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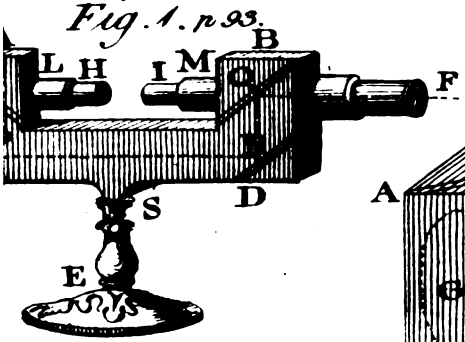

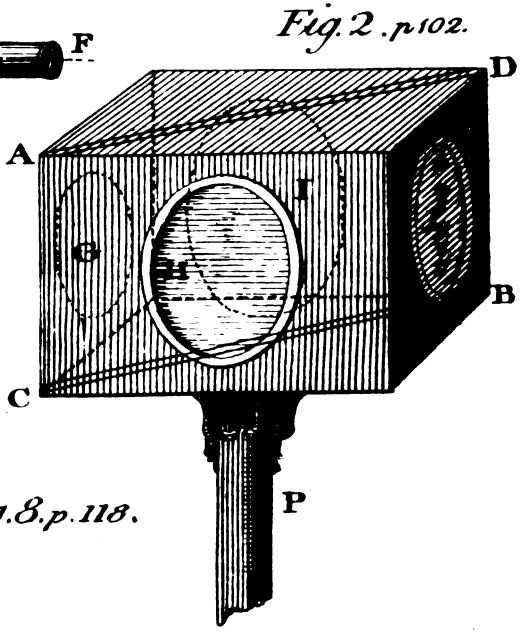

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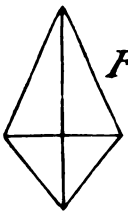

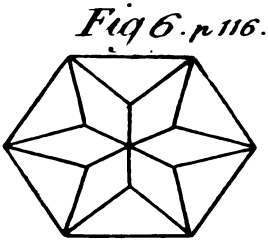

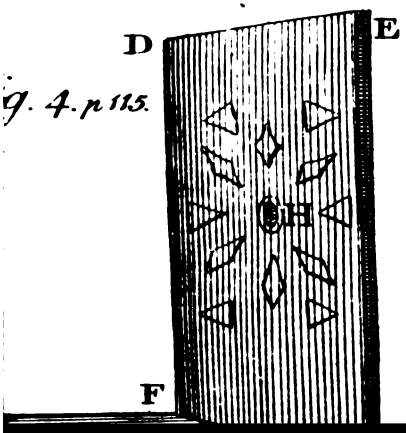

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Rational recreations

William Hooper

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DESCRIPTION of the PLATES.

PLATE I. p. 8.

FIG. I. Shows the manner in which the rays of light converge and diverge.

Fig. 2. Different objects seen under the same optic angle.

Fig. 3. The refraction of a ray of light, AB, in passing through different mediums.

Fig. 4. The different sorts of lenses.

PLATE II. p. 12.

Fig. 1. The disposition of the lenses of a common telescope. AB the object-glass, CD the eye-glass; O I the object, which appears inverted at E, and magnified.

Fig. 2. The construction of a terrestrial telescope, in which the lenses CD and EF are added to those in the last figure, and by which the object is made to appear in its natural position.

Fig. 3. Shows the structure of a reflecting telescope. GH is a large concave metalline mirror,

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perforated at *r*, by which the image of an object, entering at the end of the tube DE, is reflected to the ſmall mirror I, placed on a ſtand, and by that to the glaſſes B and A, which convey it to the eye in an erect poſition.

Fig. 4. The conſtruction of a double microſcope. A B the object-glaſs, and C D the eye-glaſs: *g m h* the object, and GH the image, which appears inverted and greatly magnified.

PLATE III. p. 36.

Fig. 1, is a veſſel with water, by the refraction of the light through which three pieces of money E, F, G, are ſeen at the point where they were inviſible before the water was poured into the veſſel.

Fig. 2. Three ſmall pieces of paper A, B, C, being ſtuck againſt the wall, the image of one of them will at a little diſtance fall on the optic nerve at D, and therefore be inviſible.

Fig. 3. The portable camera obſcura. E is a plate of glaſs placed in the frame ABCD, to which the image of the objects that enter the tube O, are reflected by the mirror N. The four legs and the pieces that compoſe the caſe H, have hinges, by which they fold up.

Fig. 4. The magic lantern. ABCD is a tin box, in one end of which is a concave mirror G; at the oppoſite end is a convex lens L, and before it a tin tube O, that has an opening MN, through which are paſſed the glaſſes that have the objects painted

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painted on them. In the tube O is placed another that is moveable, and that contains two lenſes P and Q, by which the objects on the glaſſes are thrown on the wall: K is a lamp, and E, F the funnel by which the ſmoke comes out, and its cover that keeps in the light.

PLATE IV. p. 50.

Fig. 1, and 2, are two plates of glaſs, to paſs through the groove in the magic lantern at the ſame time, and by which the appearance of a tempeſt is to be exhibited.

Fig. 3, is a box that contains a chafingdiſh, on the ſmoke of which, that comes out at the top of the box AB, the figures of a magic lantern are thrown.

Fig. 4. A machine for repreſenting a phantom: within it is placed a magic lantern, the images of which being reflected by the mirror M, paſs out at an opening in the top of the box, and are thrown on the ſmoke of a chafingdiſh placed upon it, where they are viſible.

Fig. 5. A large magic lantern for exhibiting a magical theatre. In the tube H are ſeveral grooves in different directions, by which different glaſſes are paſſed at the ſame time.

PLATE V. p. 66.

Fig. 1. Repreſentation of an object reflected by a plain mirror. A C the object, GI the mirror, DF the image.

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Fig. 2. G I is a convex mirror, A C the object, and DF the image.

Fig. 3. G I a concave mirror, A C the object, DF the image, that appears behind the mirror, erect and magnified.

Fig. 4. G I a concave mirror, AC an object at a greater diſtance than in the laſt figure; DF the image before the mirror, inverted and diminiſhed.

PLATE VI. p. 70.

Fig 1. The box for the boundleſs gallery: EF two paſteboards cut through, and painted on both ſides; D a paſteboard painted on one ſide only, and placed before a mirror at that end of the box; C is the whole by which the objects are viewed.

Fig. 2, and 3. The painted paſteboards to place in the box, Fig. 1.

Fig. 4. The box for the four magical mirrors. ABCD the body of the box, againſt whoſe four inſides the mirrors are placed. BNLI a frame of glaſs conſiſting of four inclined plates, and one at top that is horizontal; by the latter the images placed on the bottom of the box are ſeen reflected by the mirrors.

Fig. 5. A plan for diſpoſing the objects in the box, Fig. 4.

PLATE VII. p. 80.

Fig. 1. The enchanted palace. Againſt the ſix pillars mirrors are fixed, that meet in the center, and between each triangular diviſion objects are placed, that are reflected by the mirrors. ABCDEF is the plan of the baſe of the palace.

Fig.

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Fig. 2, is a ſquare on which a regular figure is drawn, that, when transferred to the correſponding diviſions of Fig. 3, appears deformed, but when ſeen in a mirror placed at F G, from a point over B, appears exactly the ſame as on Fig. 2.

Fig. 4. The magical dial. In the drawer H is placed the dial Fig. 5, whoſe index is a touched needle that is moved by a magnetic bar under the dial-plate. At I another dial, Fig. 6, is placed, whoſe index is likewiſe a touched needle, and is regulated by that on Fig. 5. At M is an inclined mirror, that, reflecting the dial placed at I, makes it viſible at an opening in that center of the dial at the top of Fig. 4.

PLATE VIII. p. 92.

Fig. 1. The box of divination A B C D, in which are placed the tablets E, F, G, H, that each contains a magnet placed in a different poſition.

Fig. 2, the table, under which is a braſs rod that has four pivots, to which are fixed the four paſteboard circles P, Q, R, S, Fig. 3. MN is an inclined mirror placed in a drawer under the table.

Fig. 4, is the top of a box, that has three holes, and over them are placed three perſpectives like Fig. 6. Each of theſe perſpectives is fixed on a hollow pedeſtal, and contains a mirror E, by which the objects on the circle Fig. 7, that is put at the bottom of the box, are ſeen at D. There is a magnetic bar concealed in the table, on which the

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the box is placed, that moves the circle Fig. 7, by the needle in the middle of it.

Fig. 5, is a column placed on the middle of the box, and in which the ſpectators ſeem to ſee the objects ſhown by the perſpectives.

PLATE IX. p. 112.

Fig. 2. The box for the animated optic balls. IM the inclined plane, down which the ball O runs, and through the groove P, to the hole at the end of the box. K F is the mirror that reflects the inclined plane and the paintings in the box to the glaſs at E, and which is repreſented by Fig. 1. T the inclined plane for a double reflection. Fig. 4, 5, and 6, the machinery that raiſes the ball to the top of the inclined plane.

Fig. 3. The painting on the inclined plane.

PLATE X. p. 118.

Fig. 1. The penetrating perſpective. F and G are two moveable tubes. O, P, Q, R, are four inclined mirrors, that reflect the objects, entering the tube G, to the eye at F.

Fig. 2. The enchanted mirrors. A D and C B the two mirrors placed croſs the box in a diagonal.

H and

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H and L, two of the glaſſes by which the ſpectators ſee each other.

Fig. 4. The machine for ſeeing an irregular figure in a multiplying glaſs (Fig. 3.) AB the ſtand with the glaſs fixed to it; H the hole through which the image is ſeen. Fig. 5. the ruler for drawing the reflection on the board D E F G. Fig. 6, 7, and 8, projections of the glaſs.

PLATE XI. p. 126.

Fig. 1. The cylindric mirror for viewing an irregular figure drawn on the board FG, from the point of view E, where it appears regular.

Fig. 2. The method of dividing the diameter of a circle into a number of parts, which are to be transferred to the cylinder, and reflected on the board, for tracing the irregular figure.

Fig. 3. The plan for drawing the regular figure.

Fig. 4, 5, and 6. The appearances of a bottle of water before a concave mirror.

PLATE XII. p. 134.

Fig. 1. The perſpective mirror. H the concave mirror, I L the blacked paſteboard for regulating the view, G the aperture for viewing the objects placed beneath it, in the mirror.

Fig. 2. A and B two concave mirrors for firing combuſtible bodies at a diſtance. C and D their foci, in which the bodies are placed.

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Fig. 3. The machinery for the real apparition C an inverted object placed under the hole in the partition AB, and which, by the reflection of the concave mirror, appears erect at D, on the outside of the partition.

PLATE XIII. p. 160.

Fig. 1. The ray of light LI, passing through the window-shutter AB, is refracted by the prism D E F, into the spectrum P Q, that exhibits all the seven primary colours.

Fig. 2, and 3. The glasses and painted papers for representing the several colours and their gradations.

Fig. 4. The magical prism. A B C a large prism; by which a ray of light is refracted, and falls on the small prism DEF, that as it revolves on its axis appears of different colours.

Fig. 5. The prismatic camera obscura. F *f* two rays of light that being refracted by the prisms A, B, C, and *a*, *b*, *c*, form the spectrum M N, which appears to be painted with all the original colours.

PLATE XIV. p. 166.

Fig. 1. A ray of light largely refracted into the spectrum PT, the divisions of whose colours correspond to the divisions of a chord for the notes of the octave.

Fig. 2, and 3. The machine for exhibiting colorific

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lorific muſic. The ſhaded parts in Fig. 2, repreſent the colours. F. is the ſcrew on which it turns, G a wheel that is moved by the endleſs ſcrew H.

Fig. 3, is the caſe that contains the cylinder, The eight ſhaded parts in the middle are the holes through which the colours on the cylinder are ſeen; O the handle that turns the endleſs ſcrew.

PLATE XV. p. 174.

Fig. 1, 2, and 3. The plans for drawing an irregular figure that will appear regular when ſeen through a hole in the ſtand Fig. 4, placed in the proper poſition.

PLATE XVI. p. 180.

Fig. 1, 2, and 3. The plans for drawing an irregular figure, which when ſeen from two oppoſite points of view, preſents two regular figures.

Fig. 4. A paſteboard in which lines are cut, and over them the paper Fig. 5, that contains the drawing that is to be paſted.

PLATE XVII. p. 190.

Fig. 1, and 2. The apparatus for drawing an irregular figure on the baſe of a cone, that appears regular from the point H; FEG the cone; MN the poſition of a glaſs on which the regular figure is drawn, and that is projected on the cone by

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by the lamp Fig. 2, when placed in the room of the ſtand HI.

Fig. 3. The machine for drawing any object correctly. EAC the tube for viewing the object; BFDG the frame, ſhown more clearly in Fig. 4, by which the parts of the object are transferred to ſimilar diviſions on a paper.

Fig. 5. The box for illuminated proſpects. EFGH the back of the box in which the prints are placed, and behind them lamps or candles.

PLATE XVIII. p. 222.

Fig. 1, ſhows the alternate vibrations of a chord.

Fig. 2. A chord ſo divided as to ſound the ſeven concords.

Fig. 3. The apparatus for the ventoſal ſymphony. AB the vane that gives motion to the machine; C, D, G, H, I, M, wheels and pinions that ſerve to move the barrel NO, in which are a number of ſtops, that ſtrike a ſet of bells.

Fig. 4. The whiſpering gallery. A the point from whence the ſound proceeds, and is reverberated by the points DEFG, to C, where it is plainly heard.

Fig. 5. The converſive ſtatue. AB and GH are two concave mirrors; C and I their focuſſes; EF a partition that has a hole, through which a ſound iſſuing at I, is diſtinctly heard at C.

PLATE XIX. p. 240.

Fig. 1, ſhows the mechaniſm of the great organ O, O, are the handles that puſh down the bellows

TT:

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TT: *l*, *l*, are the handles that turn the rollers R, R, that by means of the arms *e*, *f*, pull out the ſliders *f*, *g*, and give liberty to the pipes placed over any row of the holes to ſound; C, D, E, &c. are the keys, which being put down open the valves V, that admit the air to the pipes: KKK is the wind-cheſt, that receives the air by the port-vent 4. X is a flute-pipe of wood; Y a trumpet-pipe of metal; Z a flute-pipe of metal.

Fig. 2, ſhows the conſtruction of a valve, with the wire that opens it and the ſpring that ſhuts it.

Fig. 3. The inſide of a flute-pipe. A B the foot, BD the body; E F the partition; B C the mouth.

Fig. 4. A reed pipe; A B the foot; C D the ſhallot or reed; K L a plate of copper fitted into the mould at I, but being looſe at its extremity K, the air makes it ſhake againſt the reed.

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RATIONAL RECREATIONS.

OPTICS.

THE ſcience of optics explains the nature of viſion, by inveſtigating the cauſes of the various phenomena that ariſe from the refraction and reflection of light. It is divided into Dioptrics, Catoptrics, and Chromatics*. The firſt treats of refraction; the ſecond, of reflection; and the laſt, of colours.

GENERAL DEFINITIONS.

1. When the rays of light that iſſue from any body, continually recede from

* Theſe terms are derived from the Greek; the firſt from the word *dioptra*, a perſpective glaſs; the ſecond from *kátoptron*, a mirror; and the laſt from *chromata*, colours.

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each other, as the rays A B and A C (Plate I. Fig. 1.) they are ſaid to diverge.

2. When rays in their progreſs draw continually nearer to each other, as the rays B F and C F, (Plate I. Fig. 1.) they are ſaid to converge.

3. That point in which converging rays all meet, is called their focus; as the point F, in the ſame figure.

4. An optic angle is the ſpace contained between two lines drawn from the extremities of any object to the eye. Thus A E B or C E D (Plate I. Fig. 2.) are the optic angles under which the objects A B and C D appear to the eye at E.

GENERAL

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GENERAL APHORISMS.

1. The motion of light is not inſtantaneous but progreſſive*.

2. All rays of light naturally proceed in right lines.

3. No object can be ſeen diſtinctly at a leſs diſtance than about eight inches.

4. To produce diſtinct viſion, the rays of light muſt be parallel when they enter the eye, and the object well illumined.

5. Rays of light that come from a far diſtant object, are to be conſidered as parallel.

6. Wherever the rays that come from all the points of an object, meet again in

* It appears, by aſtronomical obſervations, that the rays of light are 8 minutes and 13 ſeconds in coming from the ſun to the earth, which is diſtant about 82 millions of miles; their progreſs, therefore, is at the rate of about ten millions of miles in a minute; yet great as that velocity is, the diſtance of the neareſt of the fixed ſtars being four hundred thouſand times greater than that of the ſun, the light muſt be more than ſix years in coming from them to us.

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ſo many points, after they have been made to converge by refraction or reflection, they will there form an image of that object on any white body.

7. Every object ſeen by refraction or reflection, appears to be in that point from whence its rays are laſt refracted or reflected to the eye.

8. The apparent magnitude of any object is determined by the magnitude of its optic angle: therefore the objects A B and C D, (Plate I. Fig. 2.) which are ſeen under the ſame angle, will appear of equal magnitude.

Theſe, and every other aphoriſm in this part, are confirmed by all optical writers; and may be demonſtrated geometrically: but as we ſuppoſe our readers to have no other previous knowledge than that of common arithmetic, it would be ſuperfluous to inſert ſuch demonſtrations here.

DIOP-

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DIOPTRICS.

DIOPTRICS, as we have ſaid, explain the ſeveral appearances that ariſe from the refraction of light.

DEFINITIONS.

1. When a ray of light paſſing out of one medium into another of a different denſity, is turned from that ſtrait line in which it would otherwiſe proceed, into one of a different direction, it is ſaid to be refracted. Thus the ray AB, (Plate I. Fig. 3.) by paſſing out of air into the glaſs GH, is turned from its natural courſe into that of CD.

2. Any ſpherical tranſparent ~~glaſs~~ medium that converges or diverges the rays of light as they paſs through it, is called a lens.

3. Of lenſes there are five ſorts: 1. A plane or ſingle convex lens, which is plane on one ſide, and convex on the other, as A (Plate I. Fig. 4.) 2. A double convex lens, as B. 3. A plano-concave lens,

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that is plane on one ſide and concave on the other, as C. 4. A double concave, as D. And, 5. A meniſcus, which is convex on one ſide and concave on the other, as E.

4. The point C, round which the ſpherical ſurface of a lens, as A Z (Plate I. Fig. 4.) is deſcribed, is called its center: the line X Y, drawn from that center perpendicular to its two ſurfaces, is the axis; and the point V, to which the axis is drawn, is the vertex of that lens.

5. When the rays of light that paſs through a ſingle or double convex lens are brought into their ſmalleſt compaſs, that point is the focus of the lens.

6. In optical inſtruments that lens which is next the object is called the object-glaſs; and that next the eye, the eye-glaſs.

7. The diſtance between the line A B (Plate I. Fig. 3.) and the perpendicular E B, is called the angle of incidence; and the diſtance between the line CD and the perpendicular BF, is called the angle of refraction.

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APHORISMS.

1. A ray of light paſſing obliquely out of one medium into another that is denſer, will be refracted toward the perpendicular, as the ray AB (Plate I. Fig. 3.) by paſſing out of air into glaſs is refracted into C D, toward the perpendicular B F. On the contrary, a ray paſſing out of a denſer into a rarer medium, will be refracted from the perpendicular; as the ray C D, paſſing out of glaſs into air, is refracted into D I.

2. The angles of incidence, and refraction, when the lines that contain them are all equal, will have a determinate proportion to each other, in the ſame mediums: which between air and water will be as 4 to 3; between air and glaſs, as 3 to 2, nearly; and in other mediums in proportion to their denſities.

3. When an object is viewed through a glaſs whoſe two ſurfaces are parallel, it will appear of its natural dimenſions, its ſituation only being a ſmall matter altered

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in proportion to the thickneſs of the glaſs, and the obliquity of the rays.

4. All the rays of light, whether diverging, parallel, or converging, that fall on a ſingle or double convex lens, will meet in a focus behind the glaſs: and the diſtance of that focus will be greateſt in diverging, and leaſt in converging rays.

5. When parallel or converging rays, fall on a ſingle or double concave lens, they will diverge behind it. If they be diverging at their incidence, they will become more ſo by paſſing through it.

6. When an object is viewed through two convex lenſes, its apparent length, or diameter, will be to its real length, as the diſtance of the focus of the object-glaſs, is to that of the eye-glaſs.

By theſe, and the foregoing aphoriſms, we are enabled to account for the various effects of dioptric machines, as refracting teleſcopes, microſcopes, the camera obſcura, &c. For example, ſuppoſe A B the object glaſs, and C D the eye-glaſs of a te-

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Fig. 1. p 2.

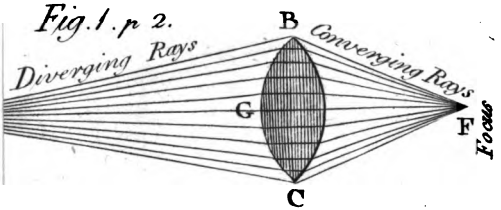


Fig. 2. p 2.

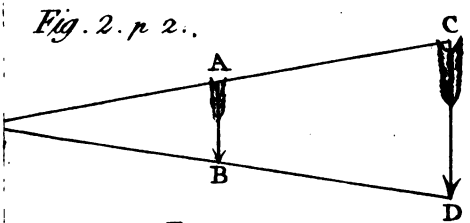


Fig. 3. p 5.

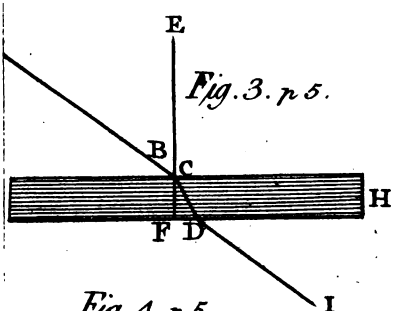
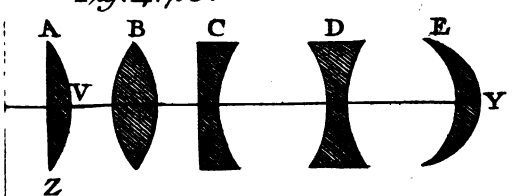


Fig. 4. p 5.



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a teleſcope, (Plate II. Fig. 1.) and let them be ſo placed that the focus of each may coincide in the point E. Suppoſe O I to be a far diſtant object, whoſe rays are therefore to be conſidered as parallel when they come to the glaſs, (aphoriſm 5. page 3.) the two rays O A, and I B, proceeding from the extremities of the object, and paſſing through the glaſs A B, will meet and interſect each other in its focus E, and paſs on to the eye glaſs C D. But E being alſo the focus of that glaſs, thoſe rays, by paſſing it, will again become parallel, and therefore by (aphoriſm 4. p. 3.) produce diſtinct viſion in the eye, placed at H.

Now ſuppoſe the diſtance between A B and E, that is, the focal length of the object-glaſs, to be 10 feet, or 120 inches, and the diſtance between E and C D, which is the focal length of the eye-glaſs, to be three inches, then, by aphoriſm 6. p 8. the apparent length or diameter of the object will be to its real length as 120 to 3,

or

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or as 40 to 1, that is, its length will be magnified 40 times, and conſequently its ſurface, if it be a ſquare, 1600 times.

It is evident, from the conſtruction of this teleſcope, that the object muſt appear to the eye inverted, but as it is principally intended for viewing celeſtial objects, that circumſtance is not much regarded. But when it is applied to terreſtrial views, two other glaſes are added. One of which, as EF, (Plate II. Fig. 2.) is placed at twice its focal diſtance from CD, and the other, GH, at the ſame diſtance from that. Now the rays being made to interſect each other again, as is evident from the figure, the object will then appear in its natural poſition.

Terreſtrial teleſcopes are ſometimes made with one object-glaſs and one concave eye-glaſs; but as only a ſmall part of an object can be ſeen by theſe at one view, they are of little uſe, except in near or large objects.

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In like manner ſuppoſe A B C D E F (Plate II. Fig. 3.) to be the tube of a reflecting teleſcope, the end DE of which is open: let G H be a large concave metalline mirror, perforated at *r*. I, a ſmaller mirror, placed on the ſtand K. Theſe mirrors are to be ſo diſpoſed that the focus of each may fall on the point *f*. Now the image of an object, as *a b*, entering the tube at D E, will fall upon the mirror G H in the points *c d*, and being reflected from thence to the focus *f*, the rays will there interſect each other, and invert the image at *g h*. This image being alſo in the focus of the mirror I, after falling on it in the points *k l*, will be reflected back in parallel rays, which paſſing through the hole *r* in the great mirror, and falling on the convex lens at B, will again croſs each other in the focus of that glaſs at *s*, which being alſo the focus of the lens at A, it will from thence be viewed by the eye at L. The principal excellence of reflecting teleſcopes ariſes from the brightneſs of the

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the reflection, by which objects appear ſo diſtinct that an eye-glaſs of a much ſmaller focus can be uſed in them than in others. The magnifying power in this, as in other teleſcopes, is as the focal diſtance of the object-glaſs or mirror, to the focal diſtance of the eye-glaſs. But the latter being ſo much ſmaller in this teleſcope, the magnifying power will be ſo much greater. Therefore, if the focal diſtance of the eye-glaſs be once inch, and that of the object-mirror 40 inches, the diameter of the object will be magnified 40 times, and its ſurface 1600 times. A reflecting teleſcope of 4 feet will magnify more than a refractor of 50 feet.

Suppoſe, again, AB (Plate II. Fig. 4.) to be the object-glaſs, and CD the eye-glaſs of a double microſcope. The object-glaſs muſt here be quite ſmall and very convex, and conſequently its focal diſtance *l f*, very ſhort. The diſtance of the ſmall object *g m h*, muſt be very little

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Fig. 1. p 9.

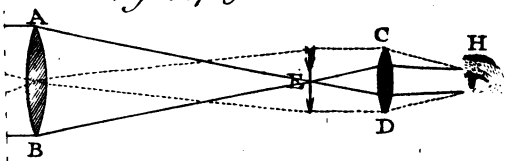


Fig. 2. p 10.

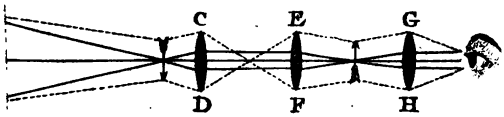


Fig. 3. p 11.

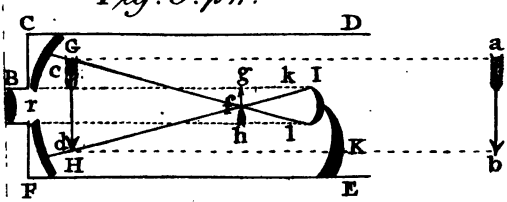
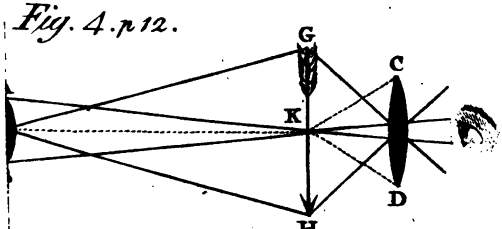


Fig. 4. p 12.



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more than that of *l f*, in order that its image G H, may be formed at a conſiderable diſtance, and conſequently be much enlarged. Now this image will appear diſtinct and conſiderably magnified, and that on two accounts: firſt, in proportion as the diſtance K *l* is greater than *l m*; and ſecondly, on account of the nearneſs of the eye to the image; for by aphoriſm 3. page 3. no object can be ſeen diſtinctly by the naked eye, at a leſs diſtance than eight inches, therefore if by means of the eye-glaſs C D, the object is made to appear diſtinct at the diſtance of one inch, it will ſeem eight times as large. Suppoſing, therefore, the focal diſtance of the eye-glaſs C D, to be once inch, and the diſtance K *l* to be to *l m* as 10 to 1, then, on both theſe accounts, the length of the object will appear 8 times 10, or 80 times, and its ſurface 6400 times, larger than when ſeen by the naked eye.

RECRE-

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RECREATION I.

Optical illuſions.

ON the bottom of the veſſel A B C D, (Plate III. Fig. 1.) place three pieces of money, as a ſhilling, a half-crown, and crown; the firſt at E, the ſecond at F, and the laſt at G. Then place a perſon at H, where he can ſee no farther into the veſſel than I: and tell him that by pouring water into the veſſel you will make him ſee three different pieces of money; bidding him obſerve carefully whether any money goes in with the water*.

When the water comes up to K, the piece at E will become viſible; when it comes up to L, the pieces at E and F will appear; and when it riſes to M, all the three pieces will be viſible.

* You muſt either pour it in very gently, or contrive to fix the pieces, that they may not move out of their places by the motion of the water.

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From what has been ſaid of the refraction of light, the cauſe of this phenomenon will be evident: for while the veſſel is empty, the ray H I will naturally proceed in a ſtraight line: but in proportion as it becomes immerſed in water, it will be neceſſarily refracted into the ſeveral directions N E, O F, P G, and conſequently the ſeveral pieces muſt become viſible.

RECREATION II.

Optical Augmentation.

TAKE a large drinking glaſs of a conical figure, that is, ſmall at bottom and wide at top; in which put a ſhilling, and fill the glaſs about half full with water: then place a plate on the top of it, and turn it quickly over, that the water may not get out. You will then ſee on the plate, a piece of the ſize of a half crown; and ſomewhat higher up, another piece of the ſize of a ſhilling.

This

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This phenomenon ariſes from ſeeing the piece through the conical ſurface of the water at the ſide of the glaſs, and through the flat ſurface at the top of the water, at the ſame time: for the conical ſurface dilates the rays and makes the piece appear larger; but by the flat ſurface the rays are only refracted, by which the piece is ſeen higher up in the glaſs, but ſtill of its natural ſize. That this is the cauſe will be farther evident by filling the glaſs with water, for as the ſhilling cannot be then ſeen from the top, the large piece only will be viſible.

After you have amuſed yourſelf with this remarkable phenomenon, you may give the glaſs to a ſervant, telling him to throw out the water, and take care of the two pieces of money; and if he have no ſuſpicion of the deception, he will be not a little ſurpriſed to find one piece only.

RECRE-

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RECREATION III.

Optical ſubtraction.

AGAINST the wainſcot of a room fix three ſmall pieces of paper, as A, B, C, (Pl. III. Fig. 2.) at the height of your eye; and placing yourſelf directly before them, at a few yards diſtance, ſhut your right eye and look at them with the left; when you will ſee only two of thoſe papers, ſuppoſe A and B; but altering the poſition of your eye you will then ſee the third and one of the firſt, ſuppoſe A; and by altering your poſition a ſecond time, you will ſee B and C; but never all three of them together.

The cauſe of this phenomenon is, that one of the three pencils of rays that come from theſe objects, falls on the optic nerve at D; whereas to produce diſtinct viſion it is neceſſary that the rays of light fall on ſome part of the retina E, F, G, H. We

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We ſee by this experiment, one of the uſes of having two eyes; for he that has one only, can never ſee three objects placed in this poſition, nor all the parts of one object of the ſame extent, without altering the ſituation of his eye.

RECREATION XI.

Alternate Illuſion.

WITH a convex lens of about an inch focus, look attentively at a ſilver ſeal, on which a cypher is engraved. It will at firſt appear cut in, as to the naked eye; but if you continue to obſerve it ſome time, without changing your ſituation, it will ſeem to be in relief, and the lights and ſhades will appear the ſame as they did before. If you regard it with the ſame attention ſtill longer, it will again appear to be engraved: and ſo on alternately.

If you look off the ſeal for a few moments, when you view it again, inſtead

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ſtead of ſeeing it, as at firſt, engraved, it will appear in relief.

If, while you are turned toward the light, you ſuddenly incline the ſeal, while you continue to regard it, thoſe parts that ſeemed to be engraved will immediately appear in relief: and if, when you are regarding theſe ſeeming prominent parts, you turn yourſelf ſo that the light may fall on the right hand, you will ſee the ſhadows on the ſame ſide from whence the light comes, which will appear not a little extraordinary. In like manner the ſhadows will appear on the left, if the light fall on that ſide. If inſtead of a ſeal, you look at a piece of money, theſe alterations will not be viſible, in whatever ſituation you place yourſelf*.

* It has been ſuſpected that this illuſion ariſes from the ſituation of the light; and in fact I have obſerved, (ſays M. Guyot, from whom this article is taken) that when I have viewed it with a candle on the right, it has appeared engraved, but

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RECREATION V.

The camera obſcura, or dark chamber.

WE ſhall here give a ſhort deſcription of this optical invention; for though it is very common, it is alſo very pleaſing, and though almoſt every one has ſeen it, every one knows not how to conſtruct it.

by changing the light to the left ſide, it has immediately appeared in relief. It ſtill, however, remains to be explained, why we ſee it alternately hollow and prominent, without changing either the ſituation or the light. Perhaps it is in the ſight itſelf that we muſt look for the cauſe of this phenomenon; and this ſeems the more probable, as all theſe appearances are not diſcernible by all perſons.

A phenomenon like this will appear to a ſuperficial obſerver a very trifling matter: but the philoſopher, who is deſirous of explaining all the appearances of nature, will find it attended with no trifling difficulties. It is, moreover, by inveſtigating the cauſes of phenomena ſeemingly inſignificant, that the moſt important diſcoveries are ſometimes made.

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Make a circular hole in the ſhuttter of a window, from whence there is a proſpect of the fields, or any other object not too near; and in this hole place a convex glaſs, either double or ſingle, whoſe focus is at the diſtance of five or ſix feet*. Take care that no light enter the room but by this glaſs: at a diſtance from it, equal to that of its focus, place a paſteboard, covered with the whiteſt paper †; let it be two feet and a half long, and eighteen or twenty inches high: bend the length of it, inwards, to the form of part of a circle, whoſe diameter is equal to double the focal diſtance of the glaſs. Then fix it on a

* The diſtance ſhould not be leſs than three feet; for if it be, the images will be too ſmall, and there will not be ſufficient room for the ſpectators to ſtand conveniently. On the other hand the focus ſhould never be more than 15 or 20 feet, for then the images will be obſcure, and the colouring faint. The beſt diſtance is from 6 to 12 feet.

† This paper ſhould have a black border, to prevent any of the ſide rays from diſturbing the picture.

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frame of the ſame figure, and put it on a moveable foot, that it may be eaſily fixed at that exact diſtance from the glaſs where the objects paint themſelves to the greateſt perfection. When it is thus placed, all the objects that are in the front of the window will be painted on the paper, in an inverted poſition*, with the greateſt regularity and in the moſt natural colours.

If you place a moveable mirror without the window, by turning it more or leſs,

* This inverted poſition of the images may be deemed an imperfection, but it is eaſily remedied: for if you ſtand above the board on which they are received, and look down on it, they will appear in their natural poſition: or if you ſtand before it, and placing a common mirror againſt your breaſt in an oblique direction, look down in it, you will there ſee the images erect, and they will receive an additional luſtre from the reflection of the glaſs; or place two lenſes, in a tube that draws out; or, laſtly, if you place a large concave mirror at a proper diſtance before the picture, it will appear before the mirror, in the air, and in an erect poſition.

you

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you will have on the paper all the objects that are on each ſide of the window*.

If inſtead of placing the mirror without the window you place it in the room, and above the hole (which muſt then be made near the top of the ſhutter), you may receive the repreſentation on a paper placed horizontally on a table; and draw at your leiſure, all the objects that are there painted.

Nothing can be more pleaſing than this Recreation, eſpecially when the objects are ſtrongly enlightened by the ſun: and

* There is another method of making the dark chamber, which is by a ſcioptric ball, that is, a ball of wood, through which a hole is made, in which hole a lens is fixed: this ball is placed in a wooden frame, in which it turns freely round. The frame is fixed to the hole in the ſhutter, and the ball, by turning about, anſwers, in great part, the uſe of the mirror on the outſide of the window. If the hole in the window be no bigger than a pea, the objects will be repreſented without any lens.

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not only land proſpects, but a ſea-port, when the water is ſomewhat agitated, or at the ſetting of the ſun, preſents a very delightful appearance.

This repreſentation affords the moſt perfect model for painters, as well for the tone of colours, as that degradation of ſhades, occaſion by the interpoſition of the air, which has been ſo juſtly expreſſed by ſome modern painters.

It is neceſſary that the paper have a circular form, for otherwiſe, when the center of it was in the focus of the glaſs, the two ſides would be beyond it, and conſequently the images would be confuſed. If the frame were contrived of a ſpherical figure, and the glaſs were in its center, the repreſentation would be ſtill more accurate. If the object without be at the diſtance of twice the focal length of the glaſs, the image in the room will be of the ſame magnitude with the object.

The

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The lights, ſhades, and colours in the camera obſcura appear not only juſt, but, by the images being reduced to a ſmaller compaſs, much ſtronger than in nature: add to this, that theſe pictures exceed all others by repreſenting the motion of the ſeveral objects: thus we ſee the animals walk, run, or fly, the clouds float in the air, the leaves quiver, the waves roll, &c. and all in ſtrict conformity to the laws of nature. The beſt ſituation for a dark chamber is directly north, and the beſt time of the day is noon.

RECREATION VI.

To ſhew the ſpots on the ſun's diſk, by its image in the camera obſcura.

PUT the object-glaſs of a ten or twelve foot teleſcope into the ſcioptric ball, and turn it about till it be directly oppoſite the ſun*. Then place the paſteboard, mention-

* When the ſun is directly oppoſite the hole, the lens will itſelf be ſufficient: or by means of the

mentioned in the laſt Recreation, in the focus of the lens, and you will ſee a clear bright image of the ſun, of about an inch diameter, in which the ſpots on the ſun's ſurface will be exactly deſcribed.

As this image is too bright to be ſeen with pleaſure by the naked eye, you may view it through a lens whoſe focus is 6 or 8 inches diſtant, which at the ſame time that it prevents the light from being offenſive, will, by magnifying both the image and the ſpots, make them appear to greater advantage.

the mirror on the outſide of the window, as in the fifth Recreation, the lens will anſwer the purpoſe at any time.

RECRE-

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RECREATION VII.

To magnify ſmall objects by means of the ſun's rays let into a dark chamber.

LET the rays of light that paſs through the lens in the ſhutter be thrown on a large concave mirror, properly fixed in a frame. Then take a ſlip, or thin plate of glaſs, and ſticking any ſmall object on it, hold it in the incident rays, at a little more than the focal diſtance from the mirror, and you will ſee, on the oppoſite wall, amidſt the reflected rays, the image of that object, very large, and extremely clear and bright. This experiment never fails to give the ſpectator the higheſt ſatisfaction.

RECRE-

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RECREATION VIII.

The portable camera obſcura.

THE great pleaſure produced by the camera obſcura in the common form, has excited ſeveral to render it more univerſally uſeful by making it portable; eaſily fixed on any ſpot, and adapted to every proſpect. We ſhall not here examine the merits of the various ſorts that have been invented, among which there are doubtleſs ſeveral highly ingenious; but content ourſelves with deſcribing one that may have ſome advantages not to be found in others*.

Let ABCD (Pl. III. Fig. 3.) be a frame of wood, of two feet long and about twenty inches wide; let its four ſides be two inches and a half thick, and firmly joined together. In a groove formed in this

* This ſort of portable camera appears to be the invention of M. Guyot.

frame

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frame place a plate of clear glaſs, E*. To each of the corners of this frame join a leg, with a hinge, that it may turn up, under the table. To the under part of the frame join four pieces of light wood, as H, which muſt alſo have hinges to fold up; and obſerve that when they are let down, as in the figure, they muſt cloſely join, by means of hooks, it being quite neceſſary that no light enter the box †.

To that juſt deſcribed, there muſt be added a ſmaller box M, in which muſt be an inclined mirror N, and in one of its ſides a moveable tube O, five or ſix inches long. This tube muſt be furniſhed with a convex glaſs, the focus of which, by the reflection of the mirror, muſt reach the glaſs E in the frame.

* If the upper ſide of the glaſs were convex, it would be ſtill better.

† The inſide of the box may be lined with black cloth, to make it as dark as poſſible.

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There muſt alſo be a covering of black ſtuff, in form of a tent, to place over the top of the frame, by means of four little poles that go into holes in the corners of it. There muſt be an opening to this tent on the ſide A B, by a curtain to be drawn up, and which you are to let down over you, when you place yourſelf under it; that no light may enter. The three other ſides ſhould hang down ſome inches over the frame.

This camera is, indeed, ſomething more cumberſome than thoſe that have been hitherto invented; and yet, if properly made, it will not weigh more than twenty to five-and-twenty pounds. On the other hand, it is much more convenient; for as the coloured rays of objects paint themſelves on the bottom of the glaſs in the frame, you may draw them without having your hand between the rays and their image.

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When you have placed the frame on a ſpot a little elevated, that nothing may intercept the rays from falling on the glaſs in the tube, you fix a ſheet of tranſparent varniſhed paper on the glaſs in the frame, by means of wax at its corners. Then placing yourſelf under the curtain, you trace on the paper all the outlines of the objects there repreſented, and if you think fit, you may alſo mark the extent of the ſhadows. If you want only the outlines, you may lay a thin plate of glaſs on that in the frame, and trace the ſtrokes with a pencil and carmine. After which you muſt dip a ſheet of paper in water, without making it too wet, and ſpreading it lightly over that glaſs, you will have the impreſſion of the deſign there drawn.

Note, By each of theſe methods you will have the objects either in their natural poſition, or reverſed; which will be an advantage when the deſign is to be engraved, and you will have it then appear in the natural poſition.

In

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In uſing this machine, you ſhould make choice of thoſe objects on which the ſun then ſhines, as the appearance of the ſhadows adds greatly to the beauty of the deſign. There are, however, circumſtances in which it is to be avoided, as when you would paint a riſing or ſetting ſun, &c.

RECREATION IX.

The magic lantern.

THIS very remarkable machine, which is now known over all the world, cauſed great aſtoniſhment at its origin. It is ſtill beheld with pleaſing admiration, and the ſpectator very frequently contents himſelf with wondering at its effects, without endeavouring to inveſtigate their cauſe. The invention of this ingenious illuſion is attributed to the celebrated P. Kircher, who has publiſhed, on various ſciences, works equally learned, curious, and entertaining.

The

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The design of this machine is to represent at large, on a cloth or board, placed in the dark, the images of small objects, painted with transparent colours on plates of glass.

Its construction is as follows. Let ABCD (Pl. III. Fig. 4.) be a tin box, eight inches high, ten long, and six wide (or any other similar dimensions.) At the top must be a funnel E, of four inches in diameter, with a cover F, which, at the same time that it gives a passage to the smoke, prevents the light from coming out of the box.

On the side A C there is a door, by which is adjusted a concave mirror G, of metal or tin, and of five inches diameter; being part of a sphere whose diameter is eighteen inches. This mirror must be so disposed that it may be pushed forward or drawn back by means of the handle H, that enters

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the tin tube I, which is foldered to the door.

In the middle of the box muſt be placed a low tin lamp K, which is to be moveable. It ſhould have three or four lights, that muſt be at the height of the focus of the mirror G.

In the ſide BD, and oppoſite to the mirror, there muſt be an aperture of three inches wide and two inches and a half high, in which is to be fixed a convex glaſs L, of the ſame dimenſion*, whoſe focus muſt be from four inches and a half to five inches, ſo that the lamp may be

* I prefer this form for the glaſs (ſays M. Guyot) that the picture thrown upon the cloth may have the ſame form, which is much preferable to a circular aperture, through which the figures can never be completely ſeen but when they are at the center of the glaſs. It is ſurpriſing that this imperfection has been ſuffered to continue ſo long, when it is ſo eaſily remedied.

placed

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placed both in its focus, and in that of the concave mirror.

On the same side is to be placed a piece of tin M N, of four inches and a half square, having an opening at the sides of about four inches and an half high, and a quarter of an inch wide. Through this opening or groove are to pass the glasses, on which are painted the figures that are to be seen on the cloth. In this tin piece, and opposite to the glass L, let there be an aperture of three inches and a quarter long, and two inches and a quarter high, to which must be adjusted a tube O, of the same form, and six inches long. This tube is to be fixed into the piece M N. Another tube, six inches long, and moveable, must enter that just mentioned, in which must be placed two convex lenses, P and Q; that of P may have a focus of about three inches, and that of Q, which is to be placed at the extremity of the tube, one of ten or twelve inches. The distance

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between theſe glaſſes is to be regulated by their foci. Between theſe glaſſes there muſt be placed a paſteboard R, in which is an aperture of an inch wide, and 4-5ths of an inch high. By placing this tube farther in or out of the other, the images on the cloth will appear larger or ſmaller.

From what has been ſaid of the preceding machines, the conſtruction of this will be eaſily underſtood. The foci of the concave mirror, and the lens L, meeting in the flame of the lamp, they together throw a ſtrong light on the figures painted on the glaſſes that paſs through the groove M N, and by that means render their colours diſtinct on the cloth. The rays from thoſe glaſſes paſſing through the lens P are collected by the aperture in the paſteboard R, and conveyed to the lens Q, by which they are thrown on the cloth.

The lantern being thus adjuſted, you muſt provide plates of clear glaſs, of twelve

or

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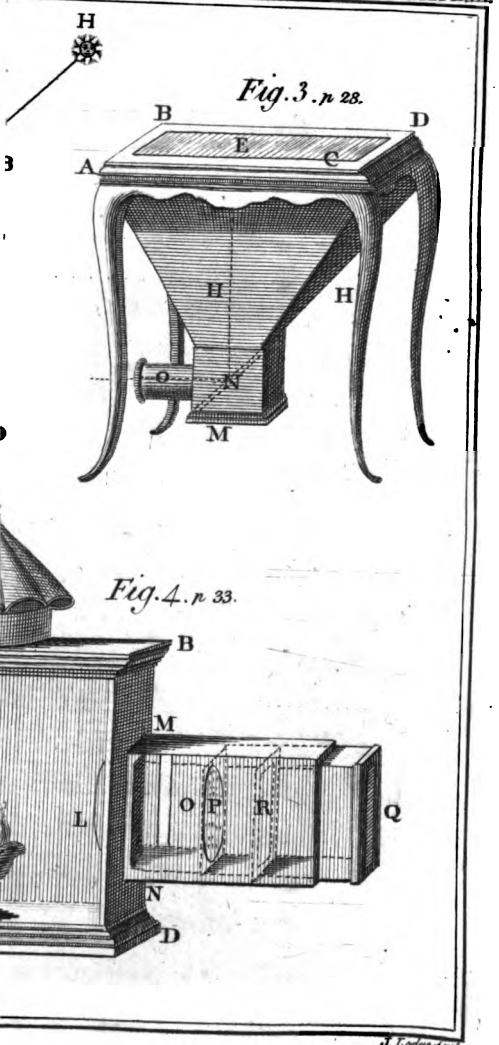

J. Ledge sculp.

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or fifteen inches long, and three inches wide, which are to be placed in thin frames, that they may paſs freely through the groove MN, after being painted in the manner we ſhall now deſcribe.

Method of painting the glaſſes for the lantern.

Draw on a paper the ſubject you intend to paint, and fix it at each end to the glaſs. Provide a varniſh with which you have mixed ſome black paint, and with a fine pencil draw on the other ſide of the glaſs, with very light touches, the deſign drawn on the paper. If you are deſirous of making the painting as perfect as poſſible, you ſhould draw ſome of the outlines in their proper colours, provided they are the ſtrongeſt tints of thoſe colours that are uſed. When the outlines are dry, you colour the figures with their proper tints or degradations; and thoſe colours will not peel off, if you temper them with a

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ſtrong white varniſh *. You are then to ſhade them with black mixed with the ſame varniſh, or with biſtre, as you find convenient. You may alſo leave ſtrong lights in ſome parts, without any colours, in order to produce a more ſtriking effect. Obſerve, in particular, not to uſe more than four or five colours, ſuch as blue, red, green, and yellow. You ſhould employ however a great variety of tints, to give your painting a more natural air, without which they will repreſent vulgar objects, which are by no means the more pleaſing becauſe they are gawdy.

When the lamp in this lantern is lighted, and by drawing out the tube to a proper length, the figures painted on the glaſs appear bright and well defined, the ſpectator cannot fail of being highly enter-

* All thoſe colours that are not terreſtrial, as Pruſſian blue, carmine, calcined verdigris, &c. may be uſed to advantage, when tempered with a proper varniſh.

tained

tained by the ſucceſſion of natural or groteſque figures that are painted on the glaſſes.

This piece of optics may be rendered much more amuſing, and at the ſame time more marvellous, by preparing figures to which different natural motions may be given *, which every one may perform according to his own taſte; either by movements in the figures themſelves, or by painting the ſubject on two glaſſes, and paſſing them at the ſame time through the groove, as will be ſeen in the next Recreation.

* There are in the Philoſophical Eſſays of M. Muſchenbroek, different methods of performing all theſe various movements, by ſome mechanical contrivances that are not difficult to execute.

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RECREATION X.

To repreſent a tempeſt by the magic lantern.

PROVIDE two plates of glaſs, whoſe frames are ſo thin that they may both paſs freely through the groove of the lantern at the ſame time.

On one of theſe glaſſes you are to paint the appearance of the ſea, from the ſlighteſt agitation to the moſt violent commotion. Repreſenting from A to B (Pl. IV. Fig. 1.) a calm; from B to C a ſmall agitation, with ſome clouds; and ſo on to F and G, which ſhould exhibit a furious ſtorm. Obſerve, that theſe repreſentations are not to be diſtinct, but run into each other, that they may form a natural gradation: remember alſo, that great part of the effect depends on the perfection of the painting, and the picturesque appearance of the deſign.

On the other glaſs (Fig. 2.) you are to paint veſſels of different forms and dimenſions,

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ſions, and in different directions, together with the appearance of clouds in the tempeſtuous parts.

You are then to paſs the glaſs (Fig. 1.) ſlowly through the groove, and when you come to that part where the ſtorm begins, you are to move the glaſs gently up and down, which will give it the appearance of a ſea that begins to be agitated; and ſo increaſe the motion till you come to the height of the ſtorm. At the ſame time you are to introduce the other glaſs with the ſhips, and moving that in like manner, you will have a natural repreſentation of the ſea, and of ſhips in a calm and in a ſtorm. As you draw the glaſſes ſlowly back, the tempeſt will ſeem to ſubſide, the ſky grow clear, and the ſhips glide gently over the waves.

This effect of the magic lantern muſt certainly afford more pleaſure and ſurprize, than to ſee figures, frequently badly painted,

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painted, appear one after the other in the midſt of a luminous circle, as in a medal; whoſe form, beſides being diſguſtful, prevents you from ſeeing any two figures, together, without the head and legs of one of them being entirely hid: an inconvenience that is avoided by this new method, even when you make uſe of the common figures.

By means of two glaſſes diſpoſed in this manner you may likewiſe repreſent a battle, or ſea fight, and numberleſs other ſubjects, that every one will contrive according to his own taſte. They may be alſo made to repreſent ſome remarkable or ludicrous action between different perſons, and many other amuſements that a lively imagination will eaſily ſuggeſt. The inſtance we here give (ſays M. Guyot) being intended merely as an example, and to ſhew that this machine is capable of producing much more remarkable effects than have been hitherto exhibited.

RECRE-

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RECREATION XI.

The nebulous magic lantern.

THE light of the magic lantern, and the colour of images, may not only be painted on a cloth, but alſo reflected by a cloud of ſmoke.

Provide a box of wood or paſteboard A B (Pl. IV. Fig. 3.) of about four feet high, and of ſeven or eight inches ſquare at bottom, but diminiſhing as it aſcends, ſo that its aperture at top is but ſix inches long, and half an inch wide. At the bottom of this box there muſt be a door that ſhuts quite cloſe, by which you are to place in the box a chafing-diſh with hot coals, on which is to be thrown incenſe, whoſe ſmoke goes out in a cloud at the top of the box. It is on this cloud that you are to throw the light that comes out of the lantern, and which you bring into a ſmaller compaſs by drawing out the moveable tube.

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tube. The common figures will here ſerve. It is remarkable in this repreſentation, that the motion of the ſmoke does not at all change the figures, which appear ſo conſpicuous that the ſpectator thinks he can graſp them with his hand.

Note, In this experiment ſome of the rays paſſing through the ſmoke the repreſentation will be much leſs vivid than on the cloth; and if care be not taken to reduce the light to its ſmalleſt focus, it will be ſtill more imperfect.

RECREATION XII.

To produce the appearance of a phantom, upon a pedeſtal placed on the middle of a table.

ENCLOSE a common ſmall magic lantern in a box A B C D (Plate IV. Fig. 4.) that is large enough to contain alſo an inclined mirror M, which muſt be moveable, that it may reflect the cone

cone of light thrown on it by the lantern, in ſuch manner that it may paſs out at the aperture made in the top of the box. There ſhould be a flap with hinges to cover the opening, that the inſide of the box may not be ſeen when the experiment is not making. This aperture ſhould likewiſe be oval, and of a ſize adapted to the cone of light that is to paſs through it.

There muſt be holes made in that part of the box which is over the lantern, to let out the ſmoke; and over that part muſt be placed a chafing-diſh of an oblong figure, and large enough to hold ſeveral lighted coals*.

There muſt alſo be a glaſs that will aſcend and deſcend at pleaſure in the vertical groove *a b*. To his glaſs let there be fixed

* This chafingdiſh may be encloſed in a painted tin box of about a foot high, with an aperture at top ſomething like Fig. 3. It ſhould ſtand on four ſhort feet, to give room for the ſmoke of the lamp to paſs out.

a cord

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a cord, that, going over a pulley *c*, paſſes out of the box at the ſide C D, by which the glaſs may be drawn up, and will deſcend by its own weight.

On this glaſs may be painted a ſpectre, or any other more pleaſing figure. Obſerve that the figures muſt be contracted in drawing, as the cloud of ſmoke does not cut the cone of light at right angles, and therefore the figures will appear longer than they do on the glaſs.

After you have lighted the lamp in the lantern, and put the mirror in a proper direction, you place the box or pedeſtal ABCD on a table, and putting the chafing-diſh in it, throw ſome incenſe in powder on the coals. You then open a trap-door, and let down the glaſs ſlowly; and when you perceive the ſmoke diminiſh you draw up the glaſs, that the figure may diſappear, and ſhut the trap door. This appearance will occaſion no ſmall ſurprize, as the ſpec-

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tre will ſeem to riſe gradually out of the pedeſtal, and on drawing up the glaſs will diſappear in an inſtant. Obſerve, that when you exhibit this Recreation you muſt put out all the lights in the room; and the box ſhould be placed on a high table, that the ſpectators may not perceive the aperture by which the light comes out. Tho' we have mentioned a ſmall magic lantern, yet the whole apparatus may be ſo enlarged, that the phantom may appear of a formidable ſize.

By having glaſſes properly painted, you may alſo produce the image of a flower, or a card, &c. like one you have burnt, and caſt the aſhes into the fire with the incenſe, and by that means pretend to make the image riſe out of the aſhes; with many other devices that every one may contrive of that kind which ſhall pleaſe him beſt.

RECRE-

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the third one: that different ſubjects of figures and decorations may be paſſed, either ſideways, aſcending, or deſcending, ſo that the ſcenes of a theatre may be the more exactly imitated*. Encloſe theſe grooves between two convex rectangular glaſſes, of ſix inches long, and five inches high, and of about twenty inches focus; one of which muſt be placed at O, and the other toward P. Have another tube Q, of about a foot long, which muſt enter that marked H; and at its outward extremity place a lens of about fifteen inches focus.

There muſt alſo be a third tube R, four inches long, which is to enter that marked I: to the exterior end of this adjuſt a concave mirror, whoſe focus muſt be at ſeven or eight inches from its reflecting ſurface.

* In the decorations, the clouds and the palaces of the Gods ſhould deſcend; caves and infernal palaces ſhould aſcend; earthly palaces, gardens, &c. enter at the ſides.

This

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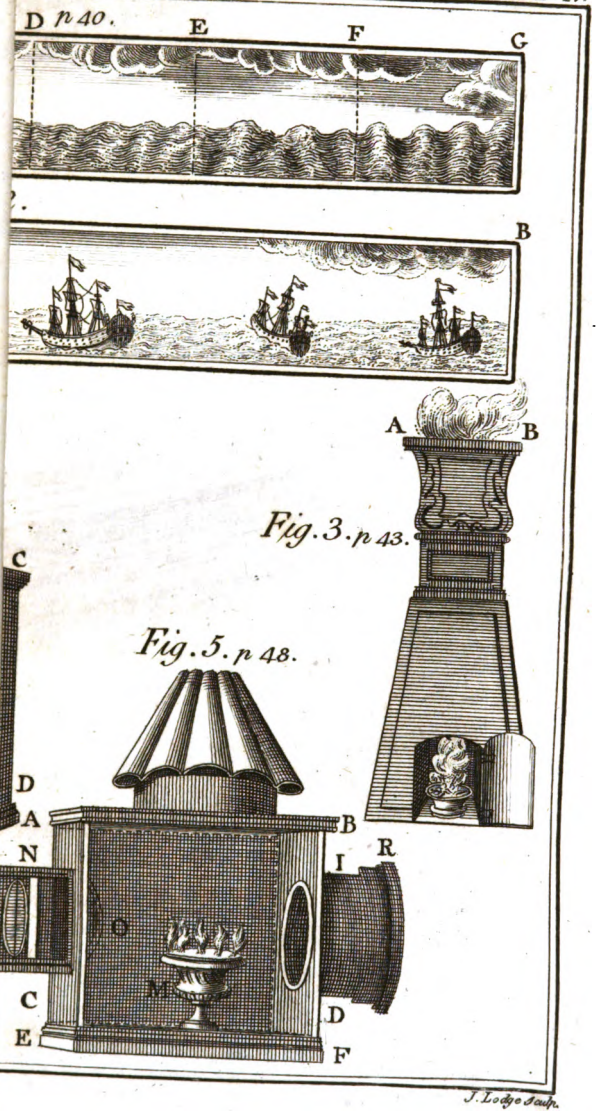

J. Lodge Sculp.

UNIV. OF MICH.
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This magic lantern being thus adjuſted, nothing more is neceſſary than to provide glaſſes, painted with ſuch ſubjects as you would repreſent, according to the grooves they are to enter. The lamp is then to be lighted, and placing a glaſs in one of the groves, you draw out the moveable tubes till the object paints itſelf on a cloth to the moſt advantage: by which you determine the diſtance of the lantern, and the ſize of the image. You then make a hole in the partition of that ſize, and fix in it a plate of clear glaſs, over which you paſte a very thin paper, which muſt be varniſhed, that it may be as tranſparent as poſſible.

It is on this paper that are to be exhibited the images of all thoſe objects, that by paſſing ſucceſſively through the groves, are to repreſent a theatric entertainment. This exhibition will be the more agreeable, as the magic lantern being concealed behind the partition, the cauſe of the

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illuſion cannot by any means be diſcovered.

In order to ſhow more clearly in what manner a ſubject of this ſort ſhould be painted, and the glaſſes diſpoſed, we will here make choice of the ſiege of Troy for a theatric ſubject; in which will be found all the incidents neceſſary to the exhibition of any other ſubject whatever.

In the firſt act, the theatre may repreſent, on one ſide the ramparts of Troy, toward the back part the Grecian camp, and at a farther diſtance, the ſea and the iſle of Tenedos. We will ſuppoſe the time to be that when the Greeks feigned to raiſe the ſiege, and embarked, leaving behind them the wooden horſe, in which were contained the Grecian ſoldiers.

On a glaſs, therefore, of the ſame width with the aperture made in the ſide A C of the box, you are to paint a deep blue curtain,

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tain, lightly charged with ornaments, quite tranſparent. This glaſs is to be placed in the firſt verticle groove, ſo that by letting it gently down*, its image may appear to riſe in the ſame m anner as the curtain of a theatre.

You muſt have ſeveral glaſſes of a proper ſize to paſs through the horizontal grooves, and of different lengths according to the extent of the ſubject. You may paint.

On the firſt, the walls of Troy.

On the ſecond, the Grecian camp.

On the third, the ſea, the iſle of Tenedos, and a ſerene ſky.

On the fourth, the Grecian troops, by detached figures.

On the fifth, other troops, diſpoſed in battalions, and placed at a diſtance.

* All the glaſſes that are to riſe and deſcend muſt be bordered with thin pieces of wood, and ſo exactly fill the grooves, that they may not ſlide down of themſelves.

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On the ſixth, divers veſſels, which as the glaſs advances in the groove diminiſh in ſize.

On the ſeventh the wooden horſe and Sinon.

On the eighth, Trojan men and women.

Theſe glaſſes being properly painted*, you place in the horizontal grooves the firſt, ſecond, third, and fourth. Then draw up the curtain, by letting down the glaſs on which it is painted, and draw away gently the fourth glaſs, and after that the ſecond; then advance, very gently, the fifth, that repreſents the embarkment, and paſs it quite through. Next paſs, the oppoſite way, the ſixth, which repreſents the Grecian fleet. The objects painted on the fourth, fifth, and ſixth quite diſappearing, you are to advance the ſeventh, on which is painted the

* Unleſs you can procure glaſſes well painted, it were better to repreſent ſome comic ſubject, where common paintings may ſuffice.

wooden

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wooden horſe, and at the ſame time the eighth, where the Trojans will appear to draw the horſe into the city. The curtain is then to be let down. that you may withdraw the ſcenes of the firſt act, and place in the grooves thoſe that are to compoſe the ſecond.

In the ſecond act may be repreſented the interior part of the city of Troy: on one ſide may be ſeen the wooden horſe, and in the back part the temple of Pallas. The glaſſes for this act may be painted in the following manner.

On the firſt, may be palaces and houſes, repreſenting the inſide of a city.

On the ſecond, the temple of Pallas in the centre, with a clear night and the moon. In the front may be ſeen the wooden horſe, that the Trojans have placed near the temple of Pallas.

On the third, a troop of Greeks, with Sinon at their head, who are going to

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open the gates of the city to the Grecians.

On the fourth, different troops of armed Greeks; painted on a long glaſs, to afford variety.

On the fifth, ſeveral troops of Trojans.

On the ſixth, various appearances of fire and ſmoke, ſo diſpoſed, that this glaſs being drawn up above the others, the objects painted on the firſt glaſs, may appear in a conflagration.

Before you draw up the curtain you ſhould place the firſt and ſecond glaſſes. You then paſs the whole third glaſs ſlowly; a little after, the fourth, on which are painted the different bodies of armed Greeks, and at the ſame time, from the oppoſite ſide, the ſixth glaſs, that repreſents the Trojan troops; obſerving to move them ſlowly both in advancing and retreating, to imitate a combat*. Then

* He that moves the glaſſes, ſeeing the effect they produce, is the better able to render the repreſentation as natural as poſſible.

draw

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draw up, by degrees, the ſixth, on which are painted the fire, flame, and ſmoke, ſo that the palaces and houſes painted on the firſt glaſs, may appear to take fire gradually, and at laſt preſent a general conflagration. After having repreſented theſe incidents with the greateſt attention, you let fall the curtain to prepare for the third act.

In the third act may be repreſented the inſide of Priam's palace, where is ſeen an altar, round which ſeveral Trojan princeſſes appear, who have fled thither for ſafety.

On the firſt glaſs may be painted the palace.

On the ſecond, a view of the back part of the palace, with the altar.

On the third, Priam with ſeveral Trojan men and women.

On the fourth, Pyrrhus, and a troop of Greeks.

On the fifth, the ſame actors, with the palace in flames.

On

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On the ſixth, A conflagration.

The two firſt glaſſes which are to be drawn up, ſhould be placed before you raiſe the curtain. Then paſs the third; next advance the fourth, which being drawn up, diſcovers on the fifth the palace in flames, then drawing up the ſixth, let down the firſt, that the palace may appear entirely deſtroyed by the conflagration.

The fourth act may repreſent the environs of Troy, with a diſtant proſpect of the ſea. The firſt and third glaſſes of the firſt act may be here uſed, to which may be added a third, repreſenting Eneas bearing his father Anchiſes, followed by his ſon Iulus, and ſome Trojans. With this glaſs may be repreſented the flight of the Trojans, and the embarkment of Eneas, with another glaſs, on which are painted certain veſſels.

To this act the following ſcenes may be added. The cave of Æolus; the back

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part of the cave; Æolus; the winds; Juno in her chariot.

The fifth act ſhould repreſent the open ſea, with the fleet of Eneas ſailing for Italy.

On the firſt glaſs muſt be painted the ſea, as in the tenth Recreation, or elſe the waves ſhould be imitated by another glaſs under the firſt.

On the ſecond, The Trojan fleet.

On the third, Neptune in his car.

On the fourth, the palace of Jupiter.

On the fifth, the inſide of the palace; the Gods aſſembled in council, with Venus, obtaining leave of Jupiter for Eneas to land in Italy.

After having placed the firſt glaſs, that repreſents a calm ſea, the curtain is raiſed, and the ſecond ſcene is advanced, which contains the Trojan fleet. The firſt is then brought forward, to repreſent a violent

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lent tempeſt: then raiſing the third glaſs, Neptune appears, who commands the waves to be ſtill, which is done by making the tempeſt ſubſide by degrees. The fleet then advances, and paſſes over the whole theatre: preſently after the fourth and fifth ſcenes deſcend, that repreſent Olympus, and finiſh the exhibition.

Note. We muſt here repeat, that if you would repreſent a ſubject of this ſort to advantage, it is quite neceſſary that the glaſſes be well painted: and thoſe that are to be in front, ſhould be in ſtronger and more opaque colours, that the images of thoſe behind may not appear mixed with them, which will be the caſe if they are all equally tranſparent.

The glaſſes ſhould alſo be of different lengths, that ſome being placed before the others are drawn away, their extremities may not be perceived.

The

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The larger theſe ſubjects are repreſented the better effect they will have: the front of the theatre ſhould appear to be about three feet wide: and, as we have ſaid elſewhere, if ſome parts of the figures were moveable it would ſtill add to the variety of the entertainment.

This and moſt of the other Recreations we have here given in the two firſt parts of Optics, appear to have been invented by M. Guyot, who has taken no ſmall pains in the improvement of this ſort of recreations.

CATOP-

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CATOPTRICS.

CATOPTRICS is that part of optics which explains the properties of reflected light, and particularly that which is reflected from mirrors.

DEFINITIONS.

1. Every poliſhed body that reflects the rays of light is called a mirror, whether its ſurface be plane, ſpherical, conical, cylindric, or of any other form whatever.

2. Of mirrors there are three principally uſed in optical experiments, which are, the plane mirror, GHI, (Plate V. Fig 1.) the ſpherical convex mirror, GHI, (Plate V. Fig. 2.) and the ſpherical concave mirror, GHI, (Plate V. Fig. 3.)

3. The point K, (Plate V. Fig. 2 and 3.) round which the reflecting ſurface of a ſpherical mirror is deſcribed, is called its centre. The line KH, drawn from its center

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center perpendicular to its two ſurfaces, is the axis of the mirror, and the point H, to which that line is drawn, is its vertex.

4. The diſtance between the lines AG and BG, (Plate V. Fig. 1.) is called the angle of incidence, and the diſtance between B G and C G is the angle of reflection.

APHORISMS.

I. In a Plane Mirror.

1. The image DF, (Plate V. Fig. 1.) will appear as far behind the mirror, as the object AC is before it.

2. The image will appear of the ſame ſize, and in the ſame poſition as the object.

3. Every ſuch mirror will reflect the image of an object of twice its own length and breadth.

4. If the object be an opaque body, and its rays fall on the mirror nearly in direct lines, there will be only one image viſible, wh

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which will be reflected by the inner ſurface of the glaſs. But

5. If the object be a luminous body, and its rays fall very obliquely on the mirror, there will appear to an eye placed in a proper poſition, ſeveral images; the firſt of which, reflected from the outer ſurface of the glaſs, will not be ſo bright as the ſecond, reflected from the inner ſurface. The following images, that are produced by repeated reflections of the rays between the two ſurfaces of the glaſs, will be in proportion leſs vivid, to the eighth or tenth, which will be ſcarce viſible.

II. In a Spherical Convex Mirror.

1. The image D F, (Plate V. Fig. 2.) will always appear behind it.

2. The image will be in the ſame poſition as the object.

3. It will be leſs than the object.

4. It will be curved, but not, as the mirror, ſpherical.

5. Parallel rays falling on this mirror will have the focus or image at half the diſtance

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diſtance of the center K, from the mirror.

6. In converging rays, the diſtance of the object muſt be equal to half the diſtance of the center, to make the image appear behind the mirror.

7. Diverging rays will have their image at leſs than half the diſtance of the center. If the object be placed in the center of the mirror, its image will appear at one-eighth of that diſtance behind it.

III. In a Spherical Concave Mirror.

1. That point where the image appears of the ſame dimenſions as the object, is the center of that mirror.

2. Parallel rays will have their focus at one half the diſtance of the center.

3. Converging rays will form an image before the mirror.

4. In diverging rays, if the object be at leſs than one half the diſtance of the center, the image will be behind the mirror, erect, curved, and magnified, as DEF (Plate V. Fig. 3.) but if the diſtance of the object be greater, the image will be before

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the mirror, inverted and diminiſhed, as DEF, (Plate V. Fig. 4.)

5. The ſun's rays falling on a concave mirror, and being parallel, will be collected in a focus at half the diſtance of its center, where their heat will be augmented in proportion of the ſurface of the mirror to that of the focal ſpot.

6. If a luminous body be placed in the focus of a concave mirror, its rays being reflected in parallel lines, will ſtrongly enlighten a ſpace of the ſame dimenſion with the mirror, at a great diſtance. If the luminous object be placed nearer than the focus, its rays will diverge, and conſequently enlighten a larger ſpace*.

IV. In all plane and ſpherical mirrors the angle of incidence is equal to the angle of reflection †.

* It is on this principle that reverberators are conſtructed.

† This aphoriſm holds true of cylindric mirrors alſo, and of thoſe whoſe ſurfaces are eliptical, parabolic, &c.

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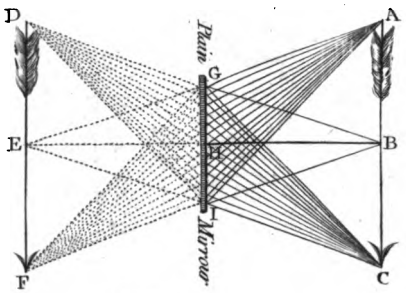

Fig. 1.
p 62.

. 2.
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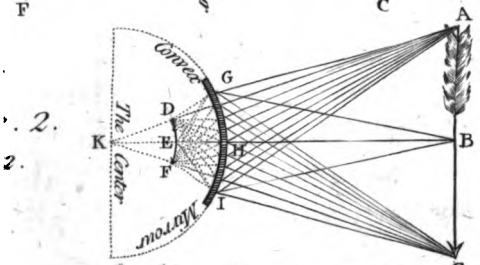

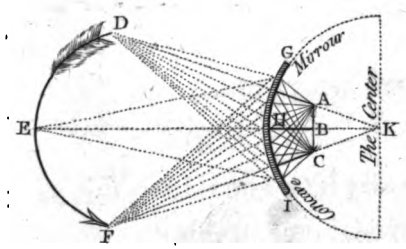

Fig. 3.
p 62.

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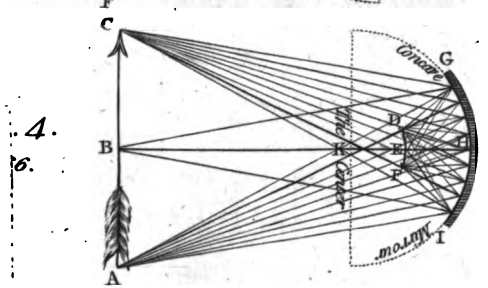

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RECREATION XIV.

The boundleſs gallery.

CONSTRUCT a box AB, (Plate VI. Fig. 1.) of about a foot long, eight inches wide, and ſix high; or what other dimenſion you ſhall think fit, provided it does not greatly vary from theſe proportions.

On the inſide of this box, and againſt each of its oppoſite ends A and B, place a mirror of the ſame ſize. Take off the quickſilver from the mirror that you place at B, for about an inch and an half, at the part C, where you are to make a hole in the box of the ſame ſize, by which you may eaſily view its inſide. Cover the top of the box with a frame, in which muſt be placed a tranſparent glaſs, covered with gauze, on the ſide next the inner part of the box. Let there be two grooves at the parts E and F to receive the two painted ſcenes hereafter mentioned. On two pieces

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of cut paſteboard let there be ſkilfully painted, on both ſides (ſee Fig. 2. and 3.) any ſubject you think proper; as woods, gardens, bowers, colonades, &c. and on two other paſteboards, the ſame ſubjects on one ſide only; obſerving that there ought to be on one of them ſome object relative to the ſubject placed at A, that the mirror placed on D may not reflect the hole at C on the oppoſite ſide.

Place the two boards painted on both ſides (Fig. 2. and 3.) in the grooves E and F; and thoſe that are painted on one ſide only, againſt the oppoſite mirrors C and D; and then cover the box with its tranſparent top. This box ſhould be placed in a ſtrong light to have a good effect.

When the eye is placed at C, and views the objects on the inſide of the box, of which ſome, as we have ſaid, are painted on both ſides, they are ſucceſſively reflected from one mirror to the other; and if, for

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for example, the painting conſiſts of trees, they will appear like a very long viſta, of which the eye cannot diſcern the end: for each of the mirrors repeating the objects, continually more faintly, contribute greatly to augment the illuſion.

RECREATION XV.

The four magical mirrors.

TAKE a ſquare box ABCD, (Plate VI. Fig. 4.) of about ſix inches long, and twelve high*; cover the inſide of it with four plane mirrors, which muſt be placed perpendicular to the bottom of the box CHFD.

Place certain objects in relief on the bottom of this box; ſuppoſe, for example, a piece of fortification, (as Fig. 5.) with tents, ſoldiers, &c. or any other ſubject

* We do not mean to limit the box to this ſize; any other may be uſed, provided, however, that it have nearly the ſame proportions.

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that you judge will produce an agreeable effect by its diſpoſition, when repeatedly reflected by the mirrors.

On the top of this box place a frame of glaſs, in form of the bottom part of a pyramid, whoſe baſe AGEB, is equal to the ſize of the box; its top ILMN, muſt form a ſquare of ſix inches, and ſhould not be more than four or five inches higher than the box. Cover the four ſides of this frame with a gauze, that the inſide may not be viſible but at the top ILMN, which ſhould be covered with a tranſparent glaſs.

When you look into this box through the glaſs ILMN, the mirrors that are diametrically oppoſite each other, mutually reflecting the figures encloſed, the eye beholds a boundleſs extent, completely covered with theſe objects; and if they are properly diſpoſed, as in the example here given, in Fig. 5. the illuſion will

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occaſion no ſmall ſurprize, and afford great entertainment.

Note, The nearer the opening ILMN is to the top of the box, the greater will be the apparent extent of the ſubject. The ſame will happen if the four mirrors placed on the ſides of the box be more elevated. The objects, by either of theſe diſpoſitions, will appear to be repeated nine, twenty-five, forty-nine times, &c. by taking always the ſquare of the odd numbers of the arithmetic progreſſion 3, 5, 7, 9, &c. as is very eaſy to conceive, if we remember that the ſubject encloſed in the box is always in the center of a ſquare, compoſed of ſeveral others, equal to that which forms the bottom of the box.

Other pieces of the ſame kind (that is viewed from above) may be contrived, in which mirrors may be placed perpendicular on a triangular, pentagon, or

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hexagon (that is, a three, five, or ſix-ſided) plane. All theſe different diſpoſitions, properly directed, as well with regard to the choice as poſition of the objects, will conſtantly produce very remarkable and pleaſing illuſions.

If inſtead of placing the mirrors perpendicular, they were to incline equally, ſo as to form part of a reverſed pyramid, the ſubject placed in the box would then have the appearance of a very extenſive globular or many-ſided figure,

RECREATION XVI.

The enchanted palace.

ON the hexagonal or ſix-ſided plane ABCDEF (Pl. VII. Fig. 1.) draw ſix ſemi-diameters GA, GB, GC, GD, GE, GF, and on each of theſe place, perpendicularly, two plane mirrors, which muſt join

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join exactly at the center G*. Decorate the exterior boundary of this piece (which is at the extremity of the angles of the hexagon) with ſix columns, that at the ſame time ſerve to ſupport the mirrors, by grooves formed on their inner ſides. (See the profile, Fig. 1.) Add to theſe columns their entablatures, and cover the edifice in ſuch manner as you ſhall think proper.

In each one of theſe ſix triangular ſpaces, contained between two mirrors, place little figures of paſteboard, in relief, repreſenting ſuch objects as when ſeen in an hexagonal form will produce an agreeable effect. To theſe add ſmall figures of enamel; and take particular care to conceal, by ſome object that has relation to the ſubject, the place where the mirrors join, which, as we have ſaid before, all meet in the common center G.

* Theſe mirrors, placed back to back, muſt be as thin as poſſible.

When

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When you look into any one of the ſix openings of this magical palace, the objects there contained being repeated ſix times, will ſeem entirely to fill up the whole of the building. This illuſion will appear very remarkable; eſpecially if the objects made choice of are properly adapted to the effect that is to be produced by the mirrors.

Note, If you place between two of theſe mirrors part of a fortification, as a curtain and two demibaſtions, you will ſee an entire citadel, with its ſix baſtions. Or if you place part of a ball-room, ornamented with chandeliers and figures in enamel, all thoſe objects being here multiplied will afford a very pleaſing proſpect.

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RECREATION XVII.

To draw an irregular figure, which ſhall appear regular when viewed in a plane mirror.

DIVIDE the ſquare A B C D (Pl. VII. Fig. 2.) into ſuch number of leſſer ſquares as you ſhall think proper, and then draw on it the ſubject you would repreſent. Make the line G F (Fig. 3.) equal to a ſide of the ſquare A B C D; and after having divided it into two equal parts at the point E, through that point draw the indefinite line A B, which muſt cut the line G F at right angles. Take any two points in the line A B, as A and B, equally diſtant from the point E, and draw from the point A the lines A C and A D, which you muſt continue till they meet the line C D, parallel to G F.

On the point A draw A H perpendicular to A B, and of an equal length with the line

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line C D, that is, double of that which forms a ſide of the ſquare A B C D.

Divide the line C D into as many equal parts as there are in a ſide of the ſquare A B C D, and from the point A draw the lines A *a*, A *b*. From the point of view H, draw the line H D, which by cutting the lines A *a*, A B, A *b*, will ſhow you the points of the ſection from which you are to draw the lines *f g*, parallel to G F and C D.

Then tranſpoſe on the trapezium, or irregular four-ſided figure, GFCD (which will be divided into as many perſpective ſquares as there are natural ſquares in Fig. 1. ABCD) the deſign traced on that ſquare; and on the line F G, place perpendicularly a mirror of an equal ſize with that ſquare. The diſtorted figure traced on the trapezium GCFD being then viewed in the mirror from a point elevated perpendicularly over the point B, to the height

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Fig. 1. p 67.

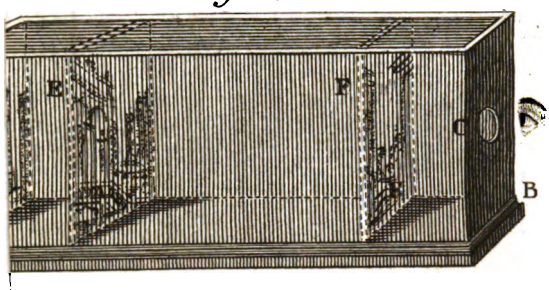


Fig. 2. p 68.

Fig. 3. p 68.

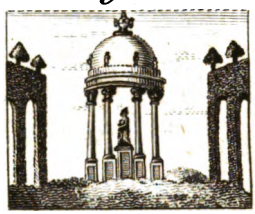


Fig. 5. p 70.

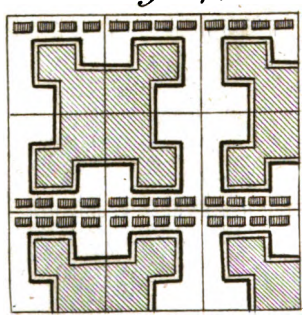
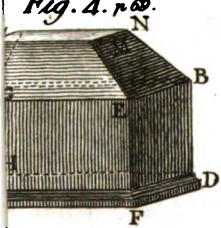


Fig. 4. p 69.



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of CD, will appear exactly similar to that traced on the square ABCD. It will appear equally regular if the mirror be taken away, and it be viewed from the point H.

Note, Before you colour the distorted figure drawn on the trapezium, you should paste it on a board of a parallelogram figure, whose sides are equal to the lines EB and CD; and fill up the space beyond the trapezium with such figures as you shall think proper, the better to disguise it: these extra figures will not appear in the mirror, if you have the precaution to raise at the point B a stand that shall bear a circle with a small hole, thro' which the object is to be seen in the mirror. This contrivance will considerably augment the illusion.

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RECREATION XVIII.

The magical dial.

PROCURE a dial-case as ABCD (Pl. VII. Fig. 4.) of the size of those that are commonly used to hold a watch. Let it be placed on a pedestal CDEF, in which there must be a small drawer H, that can hold the plate ABCD, (Fig. 5.) on which plate draw the circle of hours E, and in the center let there be a magnetic needle, placed on the point of an axis, which, passing through the plate, carries on its other point an artificial magnet, that must be concealed in the part under the plate*.

Place at the bottom of the dial case, at the part I, another dial, the hours of

* The magnetic needle itself may do, if it be not too far from the other dial. That this needle may not be suspected of having been touched it may be gilt, so as to appear like brass.

which

which are to be reverſed, as is expreſſed in Fig. 6. and whoſe hour of twelve muſt be placed next the front of the caſe G. Adjuſt a pivot to the center of this plate, and fix on it a magnetic needle.

Cover the openings at the ſides of the front of the dial-caſe (except where the dial appears) with a glaſs, lined with gauze on the inſide, that the light may paſs in and illumine the dial that is there placed. Toward the top of the dial-caſe place an inclined mirror L M, which by reflecting the dial placed at the bottom of the caſe, will make it viſible at the part N, where you muſt adjuſt a circle of paſteboard, that bordering the part where the dial appears, and being placed on the inſide, will prevent the borders or the back part of the mirror from being ſeen.

Matters being thus adjuſted, when the hand of the dial (Fig 5,) is ſet to any hour, and it is placed in the drawer, ſo that the hour

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hour of twelve may be next the ring by which it is pulled out, the hand of the other dial, placed at the bottom of the caſe, will direct itſelf to the ſame hour, and by looking at the part N, you will ſee by the reflection of the mirror, the hour appear in the front of the dial plate.

Give the dial (Fig. 5.) to any one, and tell him to ſet the hand, privately, to any hour he pleaſe, and then place it in the drawer, only obſerving that the hour of twelve be next the ring, and he will then ſee that the hand of the dial at top will direct itſelf to the ſame hour.

Note, If attention be had to place the dial-caſe ſo on the table, that the hand of the dial which is concealed (and which will of itſelf turn toward the north, when the other dial is not under it) direct itſelf to the preſent hour when the experiment is making, it will appear the more extraor-

nary;

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Fig. 3. p. 75.

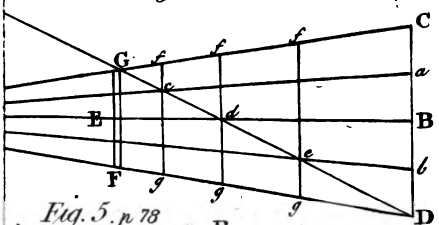


Fig. 5. p. 78

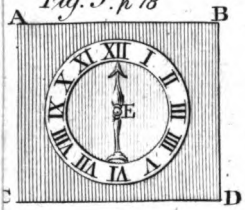
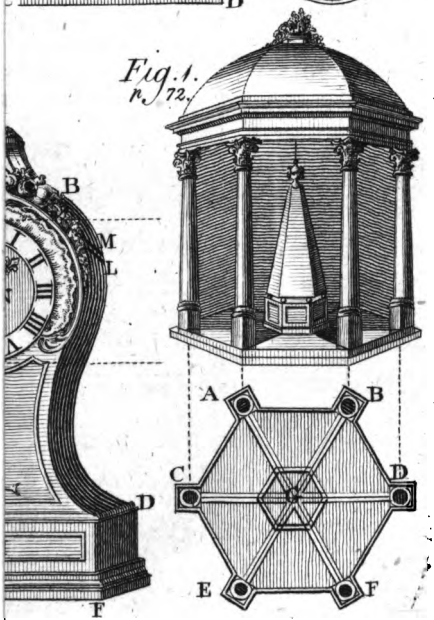


Fig. 6. p. 79.

Fig. 1. p. 72.



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dinary; becauſe, when the drawer is taken away, it will again turn to the preſent hour, which will render the cauſe of the illuſion ſtill more myſterious.

RECREATION XIX.

The box of divination.

LET a box be made with hinges, like ABCD (Pl. VIII. Fig. 1.) of about eight inches long, two wide, and half an inch thick; divide the inſide of it into four equal parts, by ſmall partitions. Have four ſmall caſes E, F, G, H, which will each of them fit any of the diviſions, and in each of them you muſt fix a ſmall artificial magnet, whoſe poles are to be placed as is expreſſed in the figure. Cover theſe caſes with paſteboard or very thin ivory, on which you are to write any four figures you ſhall think fit.

To a table I L, whoſe wood is not too thick, fit a drawer, at the bottom of which

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muſt be placed an inclined mirror MN, of the ſame length and breadth with the box juſt mentioned. Under the board that forms the top of the table, and toward the ſide where the drawer opens, place a ſmall braſs rod, turned up at its extremities, and on which there muſt be four pivots, at the ſame diſtance from each other as are the centers of the caſes placed in the box. Theſe pivots are to ſupport four circles of paſteboard P Q R S (Fig. 2, and 3.) which muſt each of them have a magnetic needle.

Obſerve, that the figures on the paſteboard muſt not only be reverſed, but muſt be wrote on the under ſide, next the bottom of the drawers, that when it is opened they may be ſeen in the mirror there placed. Have regard alſo to the diſpoſition of the poles of the needles, in the manner as is clearly expreſſed in the third figure.

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Matters being thus prepared, when you have placed on the table the box and the four numbers there included, ſo that they may be exactly over the four circles of paſteboard concealed in the drawer, that is, that the centers of the one may be preciſely over the centers of the other, the needles on the circles will conform themſelves exactly to the magnets in the caſes; ſo that if an inſtant after having placed the box, you open the drawer ſo far as to ſee the mirror, you will there perceive the number that the four figures on the caſes make.

Then give the box and the four caſes to any one, and tell him to form privately any number, by placing the caſes in what order he ſhall think fit, and return you the box firmly cloſed. You then place it on the table over the circles, and opening the drawer, under pretence of taking out an opera-glaſs, you caſt your eye on the mirror, and obſerve the order of the figures

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there expreſſed. You then ſhut the drawer, and retiring to a diſtance, pretend to diſcern, by the opera-glaſs, the number you have obſerved.

RECREATION XX.

The magical perſpectives.

AT the bottom of an heptagonal or ſeven-ſided box, as A B C D E F G (Pl. VIII. Fig. 4.) of about eight inches diameter and an inch and a half deep*. Place a circle of paſteboard, of five inches and a half diameter, very light and moveable, on a pivot fixed in the center H: on this circle fix a ſtrongly magnetic needle I, and divide the circle into 21 equal parts, as is expreſſed in Fig. 7. The top of the box is to be covered with glaſs, over which you muſt paſte a ſheet of very fine paper, painted the ſame colour with the box, and

* This box ſhould be ſo conſtructed as to appear to be the pedeſtal to the three perſpectives hereafter deſcribed.

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varniſhed, that the light may eaſily paſs through it, and illumine the objects which are to be wrote or painted on the paſte-board circle. On the middle of the top of this box erect a column I (ſee Fig. 5.) ſupported on a pedeſtal M, and crowned with its capital N.

In the glaſs that covers the box there muſt be three circular holes, at equal diſtances from each other, as O, P, Q, each of them three fourths of an inch in diameter, and on each muſt be fixed, immoveable, a perſpective glaſs, like that in the ſixth figure of this plate.

Conſtruction of the perſpective glaſs.

Provide a ſtand of wood A (Fig. 6.) in which a hole is made from top to bottom, of 3-4ths of an inch in diameter; on this ſtand place the perſpective B C, which muſt have a ſecond tube D, like the common glaſſes. In the larger part of it F,

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there muſt be a ſmall oval mirror E, which inclines or is elevated as the tube D is thruſt in or drawn out. Let there be a circular hole at that part of the tube which reſts on the ſtand A, that when the mirror is inclined, you may ſee through the ſtand of the perſpective any object that ſhall be placed in the box, under one of the holes O P Q*. Let the three perſpectives ſo conſtructed be placed, immoveable, over thoſe three holes.

The combination of objects that may be drawn on the moveable circle in the box.

This circle is to be divided, as we have ſaid, into 21 equal parts, and each of theſe diviſions muſt appear under each of the openings O, P, Q, as the circle turns round on its pivot.

* At the bottom of the ſtand of each perſpective there may be placed a lens of five or ſix inches in diameter, to magnify the object.

You

You are to determine what three objects you would have appear under the three perſpectives; and ſuppoſing, for example, that they are repreſented by the numeral figures 1, 2, and 3, you will find that theſe three figures will admit of ſix combinations or different diſpoſitions, as

1,2,3. 1,3,2. 2,1,3. 2,3,1. 3,1,2. 3,2,1*.

Then place the numbers, or the objects they repreſent, in ſuch order that the firſt number, 1, of the firſt combination 1,2,3, may be in the firſt diviſion A, of the circle, (ſee Fig. 7.) the ſecond number, 2, in the eighth, and the third number, 3, in the fifteenth diviſion: that the firſt number, 1, of the ſecond combination, may be placed in the ſecond diviſion B; the ſecond number, 3, in the ninth diviſion; and the third number, 2, in the ſixteenth diviſion, &c. Having thus filled up eighteen of the diviſions with the ſix combinations of numbers, the other three are to be left blank.

* See vol. I. page 9. aphoriſm 16.

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The circle being thus prepared, is to be placed on its pivot, and to one of the ſeven ſides of the box (Fig. 4.) is to be adjuſted a lever or ſtop, that being let down on the circle, at pleaſure, may prevent it from turning.

When the three perſpectives are placed on the box, and turned toward the column erected on its center, if the ſmalleſt tube be thruſt in, it raiſes the mirror that is contained in each of them, and, by the hole B the column is ſeen. If on the contrary the ſmall tube be drawn a little way out, the mirror becomes inclined, and you then ſee one of the three objects that are placed in the box, under each opening in the ſtands of the perſpective, and theſe objects will neceſſarily appear in the order of one of the ſix combinations of which they are alone ſuſceptible.

By placing the box on the table, in which a magnetic bar, ſix inches long,

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long*, muſt be concealed, and whoſe direction you know, you may eaſily make the three objects above mentioned appear oppoſite the three holes O, P, Q, with all their changes; for nothing more is neceſſary than to place the box according to a mark that is on the table, oppoſite to which you are to place one of its ſeven ſides; and by letting down the private check you keep the circle fixed.

The amuſements that are to be made with theſe perſpectives may be varied according to the number of different objects that can be placed on the moveable circle. We ſhall content ourſelves here with giving an example in numbers, which may be applied to any other ſubject, the difference of objects making not the leaſt difference in the manner of performing this Recreation; which, when well executed,

* This bar ſhould be ſtrongly impregnated, that it may readily turn the paſteboard circle.

never

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never fails to excite the higheſt admiration.

Firſt then, you are ſo to place the moveable circle, that the three diviſions on which there is nothing wrote may appear under the three holes O, P, Q*, and the ſmall tube of the perſpectives is to be ſo diſpoſed that the mirrors on the inſide may incline to forty-five degrees †, and reflect the objects placed under thoſe holes. The perſpectives being thus diſpoſed, they are placed on the table, and liberty is given thoſe that deſire it, to look into them, as they can then ſee no object. You are then to preſent to three different perſons, three ſuch objects as you ſhall think proper ‡;

* This muſt be done privately, by means of the check, before the machine is brought to the table.

† That is, be half way between a line drawn perpendicular to the ground, and its ſurface.

‡ Theſe objects may be either numbers, flowers, cards, mottos, &c. it is only neceſſary that the circle be properly painted. You may alſo have different circles to vary the Recreation yet farther, by privately changing them.

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we will ſuppoſe here the three numbers 1, 2, 3. When each of the three perſons has made choice of one of theſe numbers, you roll the three cards on which they are wrote, altogether, and put them into the column, oppoſite to which the three perſpectives are placed; and give each perſon liberty to chooſe in which glaſs he will ſee his object *.

When the three parties have choſe their perſpectives, the box is to be placed on the table, where the bar is concealed, taking due care to ſet it in ſuch direction that the openings O, P, Q, may correſpond to thoſe parts of the circle on which the objects are wrote. A ſhort time muſt be given the circle to ſettle, and then the

* It is immaterial which glaſs the firſt perſon chooſes, before the box is placed on the table, but if the ſecond ſhould not name that under which his object is placed, the box muſt be moved; however, it is an equal chance but he does, and in that caſe they may all three ſee their objects at the ſame time.

check

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check muſt be privately let down. The three perſons then looking through the perſpective they have each of them choſe, their objects will naturally appear to them in that part of the column where their cards were placed *.

Note, It requires ſome memory to perform this Recreation with facility, as you muſt keep in mind the ſix changes of order, which the liberty you give the ſpectators to ſee through which of the glaſſes they pleaſe, requires. You may, however, to avoid charging your memory, trace on the box certain ſigns, which at the ſame time that they appear to be ornaments, may ſhow you in what direction the box is to be placed.

* You may then propoſe to each of them to make him ſee his object through another perſpective, which you do by removing the check, and putting the box in a different direction.

RECRE-

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Fig. 1. p 81.

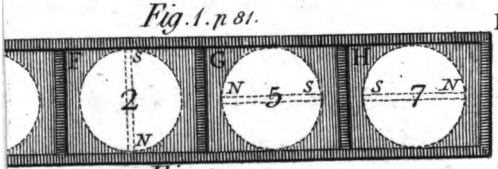


Fig. 2. p 81.

Fig. 3. p 82.

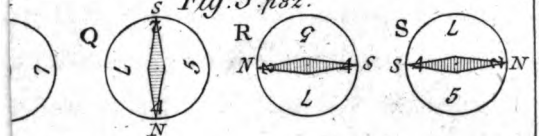


Fig. 4. p 84.

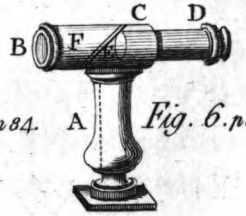
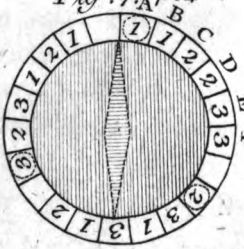


Fig. 6. p 85.

Fig. 5. p 85.

Fig. 7. A p 84



J. Lodge Sculp.

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RECREATION XXI.

The penetrating perſpective.

WITHIN the caſe ABCD, (Plate X. Fig. 1.) place four mirrors, O, P, Q, R, ſo diſpoſed that they may each of them make an angle of forty-five degrees, that is, that they may be half way inclined from the perpendicular, as in the figure. In each of the two extremities AB, make a circular overture, in one of which fix the tube GL, in the other the tube MF, and obſerve that in each of theſe is to be inſerted another tube, as H and I*.

Furniſh the firſt of theſe tubes with an object glaſs at G, and a concave eye-glaſs at F. You are to obſerve, that in regulating the focus of theſe glaſſes, with regard to the length of the tube, you are to ſup-

* Theſe four tubes muſt terminate in the ſubſtance of the caſe, and not enter the inſide, that they may not hinder the effect of the mirrors.

poſe

poſe it equal to the line G, or viſual pointed ray, which entering at the overture G, is reflected by the four mirrors, and goes out at the other overture F, where the ocular glaſs is placed. Put any glaſs you will into the two ends of the moveable tubes H and I; and laſtly place the machine on a ſtand E, moveable at the point S, that it may be elevated or depreſſed at pleaſure.

When the eye is placed at F, and you look through the tube, the rays of light that proceed from the object T, paſſing through the glaſs G, are ſucceſſively reflected by the mirrors, O, P, R, and Q, to the eye at F, and there paint the object T, in its proper ſituation, and theſe rays appear to proceed directly from that object.

The two moveable tubes H and I, at the extremities of each of which a glaſs is placed, ſerve only the more to diſguiſe the illuſion

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illuſion, for they have no communication with the interior part of the machine. This inſtrument being moveable on the ſtand E, may be directed to any object; and if furniſhed with proper glaſſes will anſwer the purpoſe of a common perſpective.

The two moveable tubes H and I being brought together, the machine is directed toward any object, and deſiring a perſon to look in at the end F, you aſk him if he ſee diſtinctly that object. You then ſeparate the two moveable tubes, and leaving a ſpace between them ſufficient to place your hand, or any other ſolid body, you tell him that the machine has the power of making objects viſible through the moſt opaque body; and as a proof you deſire him then to look at the ſame object, when, to his great ſurprize, he will ſee it as diſtinct as when there was no ſolid body placed between the tubes.

Note,

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Note, This Recreation is the more extraordinary, as it is very difficult to conceive how the effect is produced. The two arms of the caſe appearing to be made to ſupport the perſpective glaſs; and to whatever object it is directed, the effect is ſtill the ſame.

RECREATION XXII.

The magician's mirrors.

IN the wainſcot of a room make two overtures, of a foot high, and ten inches wide, and about a foot diſtant from each other. Let them be at the common height of a man's head; and in each of them place a tranſparent glaſs, ſurrounded with a frame, like a common mirror.

Behind this partition place two mirrors, one on the outward ſide of each overture, inclined to the wainſcot in an angle of forty-five degrees*; let them be both eighteen inches ſquare: let all the ſpace be-

* See page 90.

tween,

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tween them be encloſed by boards or paſte-board, painted black, and well cloſed, that no light may enter; let there be alſo two curtains to cover them, which may be drawn aſide at pleaſure.

When a perſon looks into one of theſe ſuppoſed mirrors, inſtead of ſeeing his own face he will perceive the object that is in the front of the other; ſo that if two perſons preſent themſelves at the ſame time before theſe mirrors, inſtead of each one ſeeing himſelf, they will reciprocally ſee each other.

Note, There ſhould be a ſconce with a candle placed on each ſide of the two glaſſes in the wainſcot, to enlighten the faces of the perſons who look in them, otherwiſe this experiment will have no remarkable effect.

This Recreation may be conſiderably improved by placing the two glaſſes in the

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wainſcot, in adjoining rooms, and a number of perſons being previouſly placed in one room, when a ſtranger enters the other, you may tell him his face is dirty, and deſire him to look in the glaſs, which he will naturally do; and on ſeeing a ſtrange face he will draw back: but returning to it, and ſeeing another, another, and another, like the phantom kings in Macbeth, what his ſurprize will be is more eaſy to conceive than expreſs. After this, a real mirror may be privately let down on the back of the glaſs, and if he can be prevailed to look in it once more, he will then, to his farther aſtoniſhment, ſee his own face; and may be told, perhaps perſuaded, that all he thought he ſaw before was mere imagination.

How many tricks leſs artful than this, have paſſed in former times for ſorcery; and paſs at this time, in ſome countries, for apparations?

Note, When a man looks in a mirror that is placed perpendicular to another, his face

face will appear entirely deformed. If the mirror be a little inclined, ſo as to make an angle of eighty degrees (that is one ninth part from the perpendicular) he will then ſee all the parts of his face except the noſe and forehead. If it be inclined to ſixty degrees (that is, one third part) he will appear with three noſes and ſix eyes: in ſhort, the apparent deformity will vary at each degree of inclination; and when the glaſs comes to forty-five degrees, (that is, half way down) the face will vaniſh. If inſtead of placing the two mirrors in this ſituation, they are ſo diſpoſed that their junction may be vertical, their different inclinations will produce other effects; as the ſituation of the object relative to theſe mirrors is quite different. The effects of theſe mirrors, though remarkable enough, occaſions but little ſurprize, as there is no method of concealing the cauſe by which they are produced.

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RECREATION XXIII.

Polemoſcopes.

BY the term polemoſcope is meant any inſtrument, whether catoptric or dioptric, by which you may ſee what paſſes in another place, without being ſeen from thence. Theſe machines contain one or more plane mirrors, which convey by reflection the image of the object to the eye of the ſpectator. There are ſmall inſtruments of this kind, made in the form of an opera-glaſs, by which, while you ſeem to look ſtrait forward, you ſee what paſſes on one ſide; and by that means gratify your curioſity without the appearance of incivility.

To the conſtructing of this ſort of polemoſcope nothing more is neceſſary than to fix in a common opera-glaſs a ſmall mirror inclined to an angle of forty-five degrees, and adjuſt a proper object-glaſs. This glaſs at the ſame time may anſwer its

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its common uſe, by adding an object-glaſs, and ſo contriving the ſmall tube that it may remove the mirror at pleaſure, as in the 21ſt Recreation.

The tube of a polemoſcope may be placed againſt a wall, the inclined mirror being a little above it, and turned outwards, by which means you will diſcover what paſſes on the other ſide, without being ſeen yourſelf. An inſtrument of this ſort would be of uſe in ſieges, where there is danger without the wall from the fire of the enemy; and on other occaſions. This inſtrument may be alſo ſo conſtructed, that the tube may turn round, and the mirror be elevated or depreſſed, that you may ſee ſucceſſively and at pleaſure, all the objects that you would perceive if you were at the top of the wall againſt which the inſtrument is placed.

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RECREATION XXIV.

The enchanted mirrors.

MAKE a box of wood, of a cubical figure, ACBD, (Plate X. Fig. 2.) of about fifteen inches every way. Let it be fixed on the pedeſtal P, at the uſual height of a man's head. In each ſide of this box let there be an opening of an oval form, of ten inches high, and ſeven wide.

In this box place two mirrors A, D, with their backs againſt each other; let them croſs the box in a diagonal line, and in a vertical poſition. Decorate the openings in the ſides of this box with four oval frames and tranſparent glaſſes, and cover each of them with a curtain, ſo contrived that they may all draw up together.

Place four perſons in front of the four ſides, and at equal diſtances from the box, and then draw up the curtains that they

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they may ſee themſelves in the mirrors; when each of them, inſtead of his own figure, will ſee that of the perſon who is next him, and who, at the ſame time, will ſeem to him to be placed on the oppoſite ſide. Their confuſion will be the greater, as it will be very difficult for them to diſcover the mirrors concealed in the box. The reaſon of this phenomenon is evident, for though the rays of light may be turned aſide by a mirror, yet, as we have before ſaid, they always appear to proceed in right lines.

RECREATION XXV.

The animated optic balls.
(by a ſingle reflection.)

THIS piece of catoptrics, as well as that which follows of double reflection, being of the claſs that produces the moſt pleaſing illuſion, we ſhall here give a full detail of the manner in which it is to be executed.

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Provide a wooden box ABCD, of about two feet high, and fifteen inches wide (Plate IX. Fig. 1.) and toward the top let there be made an opening E, of eight or nine inches high, and ſeven or eight inches wide, and in this opening fix a tranſparent glaſs*. Let the box be two feet deep (ſee the profile ABCD, Fig. 2.) and adjuſt to it a partition S T, of the ſame width, and that is fifteen inches deep from S to T; obſerve, that this partition will ſeparate the box into two diviſions, the upper of which muſt be one or two inches leſs than the under.

In the upper diviſion and toward the extremity S of the partition S T, and croſs it, place a ſmall decoration K S, of the figure of the outward ſcene of a theatre, in which let there be an opening of ten inches wide, and eight inches high.

* If the dimenſions of the box be larger, the exhibition will be more perfect; and on the contrary, if it be ſmaller, it will be leſs perfect.

Behind

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Behind this ſcene place the mirror KF, (Fig. 2.) in an angle of forty-five degrees, as in the common optical machines, and obſerve that it be of the ſame width with the box, and large enough to cover the overture of the front ſcene, when the eye is placed at the tranſparent glaſs E.

Decorate the interior ſpace K S B T, with ſuch different paintings as you ſhall judge will contribute moſt to the pleaſure of the exhibition. Cover the top of the box, from K to B, with a frame in which is a glaſs lined with gauze, that the light may enter the part K S B T. This firſt conſtruction being made, in the proportions and with the precautions here laid down, you are next to place the inclined plane, hereafter deſcribed, which muſt be of a ſize to enter this edifice by a back door made at G H.

Conſtruction of the inclined plane.

This plane ſhould incline to the baſe of the ſtructure in an angle of about thirty degrees,

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degrees*, that is, it ſhould be raiſed about one third of the ſpace toward the perpendicular, and muſt be ſupported on its ſides by two triangular props, placed at IML.

On that part of this plane which faces the mirror KF, draw ſome pleaſing ſubject, as, for example, a garden ornamented with bowers; or a piece of architecture, &c. in ſuch manner that it may appear regular when ſeen at E, by reflection from the inclined mirror†.

In this plane form a groove made of two thin ſlips of copper, very little elevated above the ſurface; let this groove be ſo diſpoſed that the ball in going from the

* If the ball that is to run down this plane make many turnings, the plane ſhould then have a greater inclination.

† This drawing need not differ much from the common method; for as the plane IM is but little inclined, it will be only neceſſary to draw the objects a little higher: their width may remain the ſame.

top

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top may make various windings, over ſuch parts of the drawings as you ſhall think fit, and at laſt deſcending near the middle of its inferior ſide C D. (Fig. 3.) and running along the channel O P, (Fig. 2.) it may fall into a part made to receive it in the wheel hereafter deſcribed.

Provide yourſelf with ſeveral ivory balls of ſomething more than half an inch diameter, which are to run freely in the groove above deſcribed.

On the inſide of this box, toward R, place two ſmall tin candleſticks, in which put two wax candles to enlighten the inclined plane*; there muſt be a door by which you may take them out at pleaſure: fix over them a cover of tin, to which there muſt be a funnel to carry the ſmoke out of the edifice.

* To theſe candleſticks may be joined reflectors, ſo diſpoſed as to throw all the light on the inclined plane.

Con-

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Conſtruction of the wheel for remounting the balls inceſſantly.

In the center of the toothed wheel A, (Plate IX. Fig. 5.) place a barrel with a ſpring, and let it be alſo in the center of the braſs rod FG. The pinion of the wheel B is to take the teeth of the firſt wheel A; and its teeth are to turn the fly C, whoſe wings muſt be moveable, that by being more or leſs inclined, they may accelerate or retard the motion of the machine.

To the wheel A let there be fixed two braſs rods *, and at the extremity of each there muſt be a box D, (ſee the profile Fig. 6.) whoſe overture M N is cloſed by a valve H, that moves freely on the point I: the axis of this valve muſt come out beyond the ſurface of the box, that the check L may be there placed, which

* The axis of this wheel ſhould project, that it may be wound up by a key, in the ſame manner as a clock.

ſhould

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ſhould move freely, and at the ſame time with the valve. Theſe boxes muſt be large enough to contain, each of them, one of the balls, that are, as we have ſaid, to roll on the inclined plane, and that it may enter at the ſide M of the valve, which muſt then cloſe. The ſides of theſe boxes muſt incline, as in Fig. 5.

Obſerve alſo, that this wheel muſt be of a proper ſize to place at the back of this machine, near that part where the inclined plane is placed, (ſee Fig. 4. that it may not only receive in its revolving boxes the balls, that after having rolled on the plane, paſs out by the groove O P, (Fig. 2.) but may alſo raiſe them again to the height C, (Fig. 4.) where there ſhould be a ſmall channel to receive and conduct them to the top of the inclined plane. Remark, alſo, that toward the part M there muſt be a little iron catch, that may ſucceſſively ſtop the checks L, (Fig. 6.) which are fixed to the axis of the valves, that it may

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may give time to the ball to paſs into the box at the part M, and diſcharge the check L: in like manner when the box comes to the height of the groove that is to conduct the ball to the inclined plane, there muſt be another catch to open the valve and diſcharge the ball.

The wheel being thus placed, at the back of the machine, and the ſpring wound up, the balls will inceſſantly deſcend and remount till the ſpring in the box at the axis of the wheel is quite unbent*.

When a ball is put into the groove at the top, and runs down the inclined plane, he that looks into the glaſs placed in front of the box, will imagine that it aſcends by various turnings, and goes out at the top of the edifice. The appearance will become the more pleaſing as the different

* There ſhould be a caſe over this wheel, with a door to open, that the contrivance may be quite free from detection.

windings

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windings of the ball are properly adapted to the ſubject painted on the inclined plane. This piece, when executed with care, produces a very remarkable illuſion, and is one of the moſt pleaſing Recreations of catoptrics.

RECREATION XXVI.

The ſame exhibition by a double reflection.

THIS differs from the foregoing by having a mirror inclined in an angle of forty-five degrees, (ſee Plate IX. Fig. 2.) in the room of the inclined plane, and by having the plane on which the balls roll placed near the part of the box TD.

There may be placed, moreover, toward ST, and in a poſition almoſt horizontal, little columns, arbours, or other objects, made of braſs wire, at equal diſtances *,

* This wire ſhould have a ſmall inclination, which may be two tenths of an inch for every foot; and the diſtance between the wires ſhould be ſomething leſs than the diameter of the balls.

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and joined together at the bottom by ſemi-circles, which muſt be ſo contrived as not to obſtruct the courſe of the ball.

If there be ſufficient room, you may place, under the former, another range of wires, that have a ſimilar diſpoſition, ſo that the ball, after having run over the firſt, may deſcend to the other, which will have a remarkable effect; as the balls will ſeem to rencounter and paſs over each other. There muſt then be two conductors, ſo that one ball may enter at one ſide, and the other at the oppoſite ſide. There ſhould alſo be a third conductor, which, after the ball has paſſed over the firſt piece, may carry it to the top of the inclined plane, placed oppoſite the ſecond mirror, that it may then paſs through all its windings.

Note. Theſe exhibitions may be varied at pleaſure, as that depends entirely on the taſte and invention of thoſe that conſtruct

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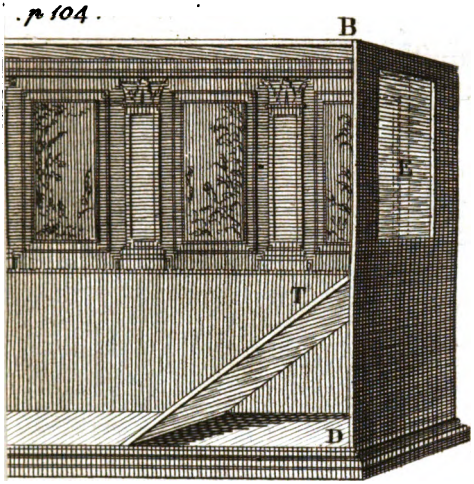
p 104.



109

Fig. 3. p 107.

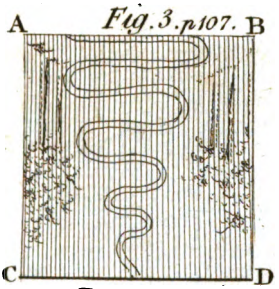


Fig. 5. p 108.

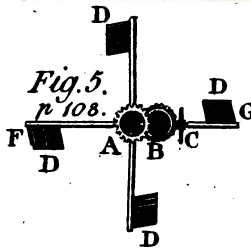


Fig. 6. p 108.

J. Lodge sculp.

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ſtruct them. You ſhould obſerve to give but a very ſmall inclination to the grooves in which the balls run. Theſe balls may be of ivory painted, as thoſe of braſs make too much noiſe in the box, and are ſubject to break the inclined mirror, when by chance they jump out of the groove and fall on it.

The grooves ſhould be concealed as much as poſſible by paintings or ornaments. They ſhould be either of braſs, tin, or thin paſteboard. In a word, too much care cannot be taken in conducting exhibitions of this nature.

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RECREATION XXVII.

To deſcribe on a plane ſurface an irregular figure, which ſhall appear regular when placed oppoſite a multiplying glaſs, and ſeen by reflection through an aperture made in the center of the drawing.

WE ſhall not here lay down the geometric manner of drawing this figure, for it would not only be very complicate, and extremely difficult to execute, but when done could not ſucceed, on account of the impoſſibility of procuring glaſſes of this ſort, whoſe planes are equally inclined and perfectly regular.

CONSTRUCTION.

Procure of an able artiſt a mirror of metal (Plate X. Fig. 3.) whoſe baſe is a hexagon of about two inches and a half in diameter, and about half an inch thick at its center. Let the faces of this mirror be very truly cut, their angles very ſharp, and

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and their ſurfaces highly poliſhed. Cement this mirror to a ſtand of about half an inch thick, and let it be firmly joined by means of a ſcrew, at the point A, (Fig. 4.) which ſhould be eight or nine inches high; and let the ſtand be ſolidly fixed on the top of the box B C*.

At the end C of this box (Fig. 4.) place an upright frame with a groove, which is to remain there, and in which are to be placed the deſigns, of about fifteen inches ſquare, containing the different diſtorted figures that are to appear regular, when ſeen in the glaſs, which, as appears by the figure, will then be oppoſite to it.

In the center of the drawing make a hole of about three tenths of an inch in diameter, through which the mirror may be entirely ſeen, and which ſhould be placed

* This box may have a drawer, to contain the different paintings that are to be ſeen by the mirror: it may be eight or nine inches wide, and fifteen inches deep.

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exactly oppoſite that hole, with its baſe parallel to the drawing or picture.

Draw on a paper or paſteboard the geometric plan of the multiplying glaſs, (ſee Fig. 6.) and on that draw the deſign you would have ſeen in the mirror. Theſe preparations being made with great attention, that is, the mirror being properly fixed, and the drawing rightly adjuſted, look at the mirror through the hole H, made in the drawing, and holding the ruler A B *, by its handle D, (ſee Fig. 5.) in your left hand, move it in different directions over the drawing till its ſide C appear to the eye (remaining conſtantly at H) to be exactly even with one of the ſides of the glaſs; there keep it fixed, and taking the eye from the hole, draw with a black lead pencil, that you have ready in the other hand, a line by the

* This ruler ſhould be about three or four inches long, very thin and black. It may be made of part of the ſpring of a clock.

ruler.

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ruler. Do the ſame by the other ſides of that face of the glaſs, and then the ſpace contained between thoſe two lines will be that on which you are to tranſpoſe that part of the deſign which is drawn on the correſponding face in Fig. 3.

Do the ſame by all the other faces of the glaſs, and you will then have twelve faces that will correſpond to thoſe of the mirror, and which altogether muſt conſequently contain the entire ſubject that is traced on Fig. 6.

Theſe ſpaces not differing much from thoſe of the mirror, it will be eaſy to trace the object that has been deſigned; it will be only neceſſary to number them, to prevent any miſtake; and to place the paper or paſteboard before the mirror, after you have lightly traced the deſign; and inſpect it by the hole H, that you may diſcover and rectify any errors that may ave been made. Theſe ſpaces may alſo be ſubdi-

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vided, as well on the deſign as the diſtorted figure, in the manner expreſſed in Fig. 7, 8; and by that means the tranſpoſition will be made with ſtill greater facility.

Laſtly you ſhould fill up the vacant parts on the paſteboard with figures that have no analogy with thoſe in the original deſign and by that means render it ſtill more ſurpriſing.

This experiment will produce a moſt agreeable illuſion to thoſe who are ignorant of the manner in which it is performed: for, when looking at the point H, they cannot diſcover the leaſt reſemblance between what they ſee in the mirror, and the general deſign on the paſteboard.

Obſerve, this drawing may alſo be traced correctly enough by means of a lamp, placed at the point of view H, taking care to encloſe it in a tin caſe, and to

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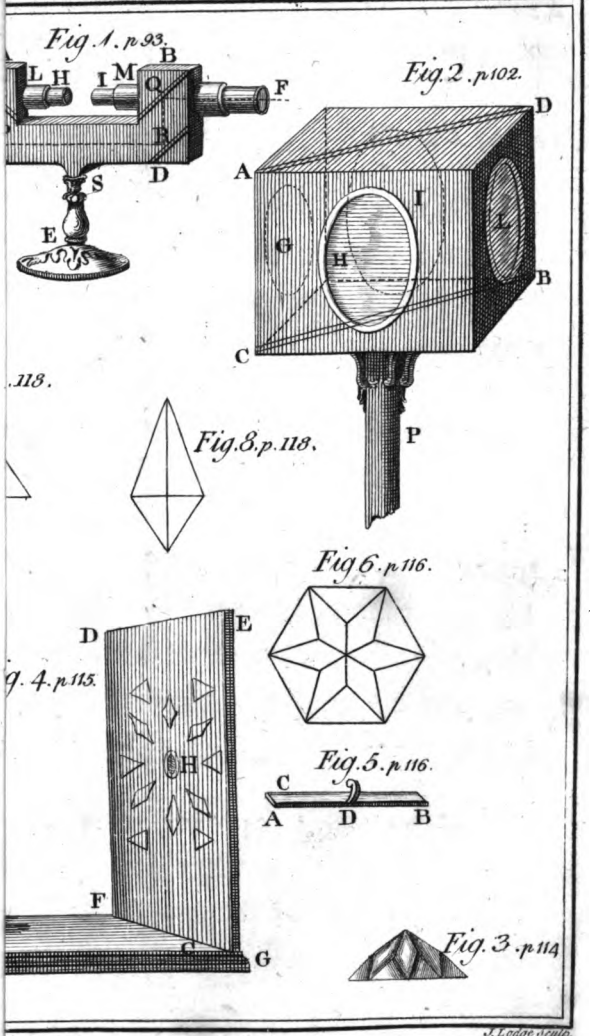

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to adjuſt to it a tube of about an inch in diameter, and three or four inches long, that can be protracted or ſhortened at pleaſure. When you uſe this method, a hole muſt be made in the paper, large enough to admit the end of the tube; ſo that the light falling on the ſeveral faces of the glaſs, they may be reflected on the paper, and ſhow where each of them is to be traced. By this method the time ſpent in finding them by the ruler is ſaved; and if the light be ſteady, the drawing will anſwer very well. You may alſo draw on the mirror, with ſoot, tempered with fine white lead, all the ſtrokes of the deſign, and by that means ſtill ſhorten the execution of the drawing.

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RECREATION XXVIII.

To describe on a plane surface a deformed figure, which shall appear regular when viewed by reflection in a cylindrical mirror.

THE geometric method of describing this irregular figure, being, as in the last Recreation, not only extremely difficult, on account of its different curves, but also liable to error from the want of regularity in making the mirrors; we shall here shew another method of describing it, far less learned indeed, but much more concise, and easily practicable by those who have not a profound knowledge of geometry, but are yet desirous of drawing these sorts of anamorphoses.

Let ABCD be the cylindrical mirror, (Plate XI. Fig. 1.) in which you would see, from

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from the point of view E, the deformed object painted on the board FG, in a regular form.

On a paper, or paſteboard, draw the circle A (Fig. 2.) equal to the baſe BD of the cylindric mirror; and taking the point B for the diſtance of the point of view from the mirror, draw the line AB, which muſt paſs through A, the center of the circle. Then draw the two lines BC and BD,

Divide the line CD into ſix equal parts, and draw from the point of view B, the lines B *i*, which by cutting one of the ſides of the circle, will determine the points on which you are to erect the parallel perpendiculars, which may be done by a ruler; making uſe of an opaque colour that will effectually obſcure thoſe parts of the cylinder where they are drawn*.

* You may uſe ſoot and white lead ground together with gum, after having traced the lines with a crayon.

Theſe

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These first divisions being regularly made, divide about two thirds of the height of the side CD, of the cylinder, into ten or twelve parts, respectively equal to those of the diameter of the circle (Fig. 2.) and from the point of view E, draw the lines E *l*, which passing through all the points of division, must be continued to the other side of the cylinder. On the two opposite sides of the cylinder mark the different heights of the several divisions, and through those points draw the oval figures *i l*, making use of the same colour as before.

Take a paper ABCD (Fig. 3.) whose two sides AB and CD must be divided into six equal parts, and those of AC and BD into ten or twelve equal parts, on which you are to draw the figure as you would have it appear to the eye when viewed in the cylindric mirror. At the point of view E, place a lamp so disposed that its light may fall on the cylindric mirror only.

When

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When you have fixed the cylinder on the paſteboard F G (Fig. 1.) and the lamp is placed at E, ſo that its light cannot fall on the paſteboard, but by reflection, all the ſtrokes on the cylinder will then appear on the board, and may be eaſily traced with a pencil. By this means the board will be divided into as many irregular ſpaces, as there are regular diviſions in the parallelogram (Fig. 8.) If, therefore, you transfer to each of thoſe ſpaces the ſtrokes of the deſign that is on the parallelogram, it will appear quite deformed on the paſteboard, and quite regular when ſeen from the point of view E, eſpecially if due attention be had to drawing the outlines of the figure.

Note, The point of view ſhould be four or five inches above the upper part of the mirror, that you may not be obliged to make uſe of a very large paſteboard: it ſhould not, however, be much higher, as then the figure on the board would not be ſufficiently deformed.

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By this method you may alſo draw irregular figures to be ſeen in a priſm, or any other ſort of mirror, provided they can be traced and illuminated*.

Obſerve, if you are deſirous of painting theſe ſorts of anamorphoſes to advantage, you muſt not overcharge thoſe parts with colour that are moſt diſtended, for when they become contracted in the mirror the colours appear unnatural. In a word, great attention is neceſſary in drawing and painting theſe ſubjects, as on that the ſucceſs principally depends.

* The geometric method of drawing deformed objects to be ſeen in a priſm, will be found at large in the treatiſe of Abbé Nollet.

RECRE-

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RECREATION XXIX.

Optical appearances.

OF all our ſenſes the ſight is certainly ſubject to the greateſt illuſion. The various writers on optics have deſcribed a great number of inſtances in which it deceives us, and have conſtantly endeavoured to inveſtigate the cauſes, to explain their effects, and to reconcile appearance with reality. We every day diſcover new phenomena, and doubtleſs many more are reſerved for poſterity. It frequently happens, moreover, that a diſcovery which at firſt ſeemed of little conſequence, has led to matters of the higheſt importance.

Take a glaſs bottle A, (Pl. XI. Fig. 4.) and fill it with water to the point B; leave the upper part BC, empty, and cork it in the common manner. Place this bottle oppoſite a concave mirror, and beyond its focus, that it may appear reverſed, and before

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fore the mirror (see aphorism 4. page 65.) Place yourself still farther distant than the bottle, and it will appear to you in the situation *a*, *b*, *c*, (Fig. 5.)

Now its is remarkable in this apparent bottle, that the water, which, according to all the laws of catoptrics, and all the experiments made on other objects, should appear at *a b*, appears on the contrary at *b c*, and consequently the part *a b* appears empty.

If the bottle be inverted and placed before the mirror (as in Fig. 6.) its image will appear in its natural, erect position; and the water, which is in reality at BC, will appear at *a b*.

If while the bottle is inverted it be uncorked, and the water run gently out, it will appear that while the part BC is emptying, that of *a b* in the image is filling; and what is likewise very remarkable,

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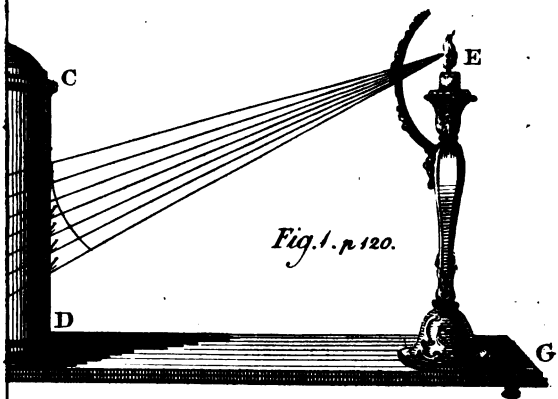
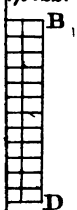


Fig. 1. p 120.

p 122.



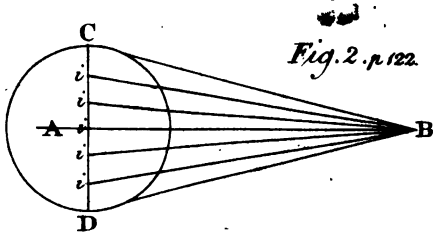


Fig. 2. p 122.

Fig. 5. p 126.

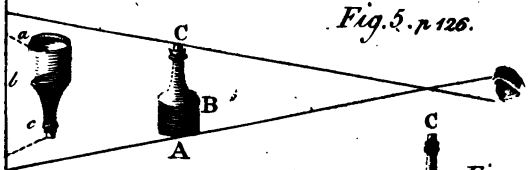
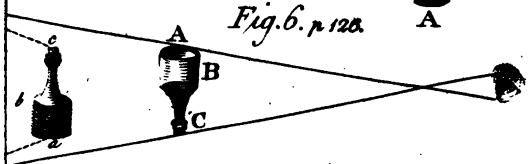


Fig. 4. p 125.

Fig. 6. p 126.



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able, as ſoon as the bottle is empty the illuſion ceaſes, the image alſo appearing entirely empty. If the bottle likewiſe be quite full there is no illuſion.

If while the bottle is held inverted, and partly empty, ſome drops of water fall from the bottom A towards B C, it ſeems in the image as if there were formed at the bottom of the part *a b*, bubbles of air that roſe from *a* to *b*; which is the part that ſeems full of water. All theſe phenomena conſtantly appear.

The remarkable circumſtances in this experiment, are, firſt, not only to ſee an object where it is not, but alſo where its image is not; and ſecondly, that of two objects which are really in the ſame place, as the ſurface of the bottle and the water it contains, the one is ſeen at one place, and the other at another; and to ſee the bottle in the place of its image, and the water where neither it, nor its image, are.

Note,

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Note, It has been conjectured, with ſome appearance of reaſon, that this illuſion ariſes partly from our not being accuſtomed to ſee water ſuſpended in a bottle with the neck downward, and partly from the reſemblance there is between the colour of the air and that of water, which induces us to imagine that we ſee them where they uſually are; and this is rendered more probable by putting any coloured liquor into the bottle, for that will appear in its proper place (M. Guyot)

RECREATION XXX.

The perſpective mirror.

PROVIDE a box ABCD (Pl. XII. Fig. 1.) of about two feet long, fifteen inches wide, and twelve inches high. At the end AC place a concave mirror, the focus of whoſe parallel rays is at eighteen inches from the reflecting ſurface. At IL place a paſteboard blacked, in which a hole

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a hole is cut ſufficiently large to ſee on the mirror H, the object placed at BEFD.

Cover the top of the box, from A to I, cloſe, that the mirror H, may be entirely darkened. The other part IB, muſt be covered with a glaſs, under which is placed a gauze.

Make an aperture at G, near the top of the ſide EB; beneath which, on the inſide, place, in ſucceſſion, paintings of different ſubjects, as viſtas, landſcapes, &c. ſo that they may be in front of the mirror H. Let the box be ſo placed that the object may be ſtrongly illumined by the ſun, or by wax lights placed under the encloſed part of the box AI.

By this ſimple conſtruction the objects placed at GD will be thrown into their natural perſpective, and if the ſubjects be properly choſe, the appearance will be altogether as pleaſing as in optical machines of a much more complicated form.

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Note, A glaſs mirror ſhould be always here uſed, as thoſe of metal do not repreſent the objects with equal vivacity, and are beſide ſubject to tarniſh. It is alſo neceſſary that the box be ſufficiently large, that you may not be obliged to uſe a mirror whoſe focus is too ſhort; for in that caſe, the right lines near the border of the picture will appear bent in the mirror, which will have a diſagreeable effect, and cannot be avoided.

RECREATION XXXI.

To ſet fire to a combuſtible body, by the reflection of two concave mirrors.

THE rays of a luminous body placed in the focus of a concave mirror being reflected in parallel lines, if a ſecond mirror be placed diametrically oppoſite the firſt, it will, by collecting thoſe rays in its focus, ſet fire to a combuſtible body.

Place two concave mirrors, A and B (Pl. XII. Fig. 2.) at about twelve or fifteen

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feet diſtance from each other, and let the axis of each of them be in the ſame line. In the focus C, of one of them, place a live coal and in the focus D of the other, ſome gunpowder. With a pair of double bellows, which make a continual blaſt, keep conſtantly blowing the coal, and notwithſtanding the diſtance between them the powder will preſently take fire.

It is not neceſſary that theſe mirrors be of metal or glaſs, thoſe made of wood or paſteboard, gilded, will produce the explosion, which has ſometimes taken effect at the diſtance of fifty feet, when mirrors of eighteen inches or two feet diameter have been uſed.

This experiment ſucceeds with more difficulty at great diſtances; which may proceed from the moiſture in a large quantity of air. It would doubtleſs take effect more readily, if a tin tube, of an equal diameter with the mirrors, were to be placed between them.

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RECREATION XXXII.

The real apparation.

BEHIND the partition A B (Pl. XII. Fig. 3.) place, in a poſition ſomething oblique, the concave mirror E F, which muſt be at leaſt ten inches in diameter, and its diſtance from the partition equal to three-fourths of the diſtance of its center.

In the partition make an opening of ſeven or eight inches, either ſquare or circular: it muſt face the mirror; and be of the ſame height with it. Behind this partition place a ſtrong light, ſo diſpoſed that it may not be ſeen at the opening, and may illumine an object placed at C, without throwing any light on the mirror.

Beneath the aperture in the partition place the object C, that you intend ſhall appear on the outſide of the partition, in an inverted poſition; and which we will ſuppoſe

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ſuppoſe to be a flower. Before the partition, and beneath the aperture, place a little flower pot D, the top of which ſhould be even with the bottom of the aperture, that the eye, placed at G, may ſee the flower in the ſame poſition as if its ſtalk came out of the pot.

Take care to paint the ſpace between the back part of the partition and the mirror black, to prevent any reflections of light from being thrown on the mirror; in a word, ſo diſpoſe the whole that it may be as little enlightened as poſſible.

When a perſon is placed at the point G, he will perceive the flower that is behind the partition, at the top of the pot at D, but on putting out his hand to pluck it, he will find that he attempts to graſp a ſhadow.

Obſervation.

The phenomena that may be produced by means of concave mirrors are highly

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curious and aſtoniſhing. By their aid ſpectres of various kinds may be exhibited. Suppoſe, for example, you were to tell any one, that at ſuch an hour, and in ſuch a place, he ſhould ſee the apparition of an abſent or deceaſed friend (of whoſe portrait you are in poſſeſſion.) In order to produce this phantom, inſtead of the hole in the partition A B, in the laſt figure, there muſt be a door, which opens into an apartment to which there is a conſiderable deſcent. Under that door you are to place the portrait, which muſt be inverted and ſtrongly illuminated, that it may be lively reflected by the mirror, which muſt be large and well poliſhed. Then having introduced the incredulous ſpectator at another door, and placed him in the proper point of view, you ſuddenly throw open the door at A B, when, to his great aſtoniſhment, he will immediately ſee the apparition of his friend.

It will be objected, perhaps, that this is not a perfect apparition, becauſe it is only viſible

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Fig. 1. p 128.

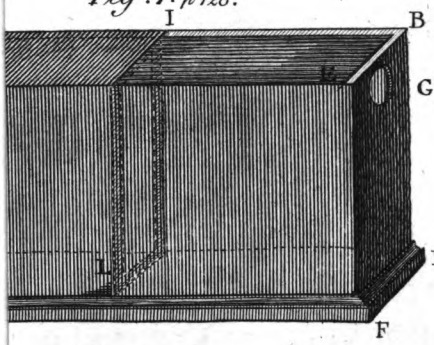
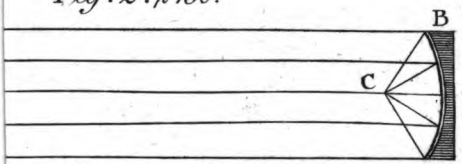


Fig. 2. p 130.



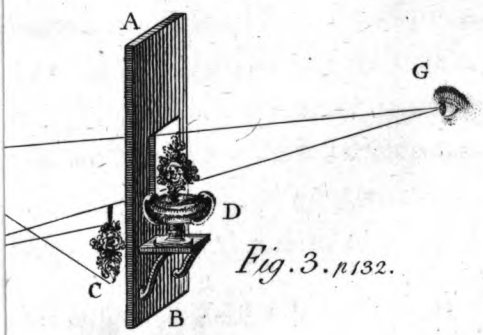


Fig. 3. p 132.

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viſible at one point of view, and by one perſon. But it ſhould be remembered, that it was an eſtabliſhed maxim in the laſt centuries, that a ſpectre might be viſible to one perſon and not to others. So Shakſpeare makes both Hamlet and Macbeth ſee apparitions that were not viſible to others, preſent at the ſame time. It is not unlikely, moreover, that this maxim took its riſe from certain apparitions of this kind that were raiſed by the monks, to ſerve ſome purpoſes they called religious; as they alone were in poſſeſſion of what little learning there then was in the world.

Nothing here ſaid is intended to invalidate the belief that ſeparate ſpirits may hold converſe with men. He muſt be either very weak or very wicked, who can wiſh to diſbelieve an opinion that is ſo highly honourable and advantageous to humanity.

There is one phenomenon we muſt not here omit; for tho' it be common enough

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it is alſo pleaſing, and eaſy to be performed. If you place yourſelf before a concave mirror, and at a proper diſtance, your figure will appear inverted, and if you ſtretch out your hand toward the mirror, you will perceive another hand that ſeems to meet and join it, though imperceptible to the touch. If inſtead of your hand you make uſe of a drawn ſword, and preſent it in ſuch manner that its point may be directed toward the focus of the parallel rays of the mirror, another ſword will appear, and ſeem to encounter that in your hand. You are to obſerve, that to make this experiment ſucceed well, you muſt have a mirror of at leaſt a foot in diameter, that you may ſee yourſelf in part. If you have a mirror large enough to ſee your whole perſon, the illuſion will be much more ſtriking. This phenomenon, with which ſo much parade has been made by ſome modern experimental philoſophers, was deſcribed by Baptiſta Porta more than 200 years ſince.

CHRO-

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CHROMATICS.

CHROMATICS is that part of optics which explains the ſeveral properties of the colours of light, and of natural bodies.

DEFINITIONS.

1. Thoſe rays of light that are all equally refrangible, are called ſimple or homogeneal rays.

2. Thoſe rays that have different degrees of refrangibility, are called compound, or heterogeneal*.

3. The colours of homogeneal light are called primary or ſimple colours: and

4. Thoſe of heterogeneal light, ſecondary or compound colours.

5. A ſpectrum is a coloured image of the ſun, produced by the refraction of a ray of light let into a dark chamber.

* The terms homogeneal and heterogeneal are derived from the Greek words *omos*, *the ſame*; *eteros*, *another*; and *genos*, *kind* or *ſpecies*.

6. A

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6. A prism is a glass body, whose two ends are similar and parallel triangles, and its three sides regular planes.

APHORISMS.

1. All the colours in nature proceed from the rays of light.

2. There are seven primary colours, which are red, orange, yellow, green, blue, indigo, and violet.

3. Every ray of light may be separated into the seven primary colours.

4. The rays of light in passing through the same medium have different degrees of refrangibility.

5. The difference in the colours of light arises from its different refrangibility, that which is the least refrangible producing red, and that which is the most refrangible, violet*.

* It is conjectured that the different refrangibility in the rays of light proceeds from their different magnitude: those of red light, being the largest, make

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6. By compounding any two of the primary colours, as red and yellow, or yellow and blue, the intermediate colour, as orange or green, may be produced.

7. The colours of bodies arise from their disposition to reflect one sort of rays, and to absorb the other. Those that reflect the least refrangible rays appearing red; and those that reflect the most refrangible, violet*.

make the strongest impression on the retina; and those of violet, being the smallest, make the weakest impression.

* It appears highly probable, from observations made by Sir Isaac Newton, that the disposition of bodies to reflect the different rays of light, arises from the different size of their particles. Thus, the azure colour of the sky, and the most luminous white, as that of metals, he supposes to be produced by particles of the first order; but if the white be less intense, as that of linen, paper, and such like substances, he conjectures that it arises from a mixture of particles of all orders. The green of vegetables he supposes to proceed from the third order, and the particles that cause blackness, to be smaller than those that produce any of the colours.

8. Such

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8. Such bodies as reflect two or more ſorts of rays, appear of various colours.

9. The whiteneſs of bodies ariſes from their diſpoſition to reflect all the rays of light promiſcuouſly.

10. The blackneſs of bodies proceeds from their incapacity to reflect any of the rays of light*.

RECREATION XXXIII.

Out of a ſingle colourleſs ray of light to produce ſeven other rays, which ſhall paint, on a white body, the ſeven primary colours of nature.

PROCURE of an optician a large glaſs priſm DEF, (Plate XIII. Fig. 1.) well poliſhed, two of whoſe ſides muſt contain an angle of about ſixty-four degrees. Make a room quite dark, and in the window ſhutter AB, cut a round hole, about

* From hence it ariſes that black bodies, when expoſed to the ſun, become ſooner heated than all others.

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one-third of an inch in diameter at C, through which a ray of light L I paſſing, falls on the priſm D E F, by that it is refracted out of the direction I T, in which it would have proceeded, into another G H, and falling on the paper M N S X, will there form an oblong ſpectrum P Q, whoſe ends will be ſemicircular, and its ſides ſtrait; and if the diſtance of the priſm from the paper be about eighteen feet, it will be ten inches long, and two inches wide.

Now this ſpectrum will exhibit all the primary colours; for the rays between P and V, which are the moſt refracted, will paint a deep violet; thoſe between V and I, indigo; thoſe between I and B, blue; thoſe between B and G, green; thoſe between G and Y, yellow; thoſe between Y and O, orange; and thoſe between O and R, being the leaſt refracted, an intenſe red*. The colours between theſe

* For this reaſon it is that the rays which are near the edges of a lens have different degrees of refraction,

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ſpaces will not be every where equally intenſe, but will incline to the neighbouring colour; thus the part of the orange next to R, will incline to a red, and that next to Y, to a yellow; and ſo of the reſt.

RECREATION XXXIV.

From two or more of the primary colours, to compoſe others that ſhall, in appearance, reſemble thoſe of the former.

BY mixing the two homogeneal colours red and yellow, an orange will be produced, ſimilar in appearance to that in the ſeries of primary colours; but the light of the one being homogeneal, and, that of the other heterogeneal, if the former be viewed through a priſm it will remain unaltered, but the other will be reſolved into its component colours, red and yellow. In like manner other contiguous

refraction, and tinge the object with different colours.

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homogenial colours may compound new colours; as by mixing yellow and green, a colour between them is formed; and if blue be added, there will appear a green that is the middle colour of thoſe three. For the yellow and blue, if they are equal in quantity, will draw the intermediate green equally toward them, and keep it, as it were in equilibrio, that it verge not more to the one than to the other. To this compound green there may be added ſome red and violet, and yet the green will not immediately ceaſe, but grow leſs vivid; till by adding more red and violet it will become more diluted, and at laſt, by the prevalence of the added colours, it will be overcome, and turned into whiteneſs or ſome other colour.

In like manner if the ſun's white, compoſed of all kind of rays, be added to any homogeneal colour, that colour will not vaniſh, nor change its ſpecies, but be diluted; and by adding more white, it will become

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become continually more diluted. Laſtly, if red and violet be mixed, there will be generated, according to their various proportions, various purples, ſuch as are not like in appearance, to the colour of any homogeneal light: and of theſe purples, mixed with blue and yellow, other new colours may be compoſed.

RECREATION XXXV.

Out of three of the primary colours, red, yellow, and blue, to produce all the other priſmatic colours, and all that are intermediate to them.

PROVIDE, three panes of glaſs of about five inches ſquare, (ſee Plate XIII. Fig. 2.) and divide each of them, by parallel lines, into five equal parts.

Take three ſheets of very thin paper, which you muſt paint, lightly, one blue, another yellow, and the third red*. Then

* You muſt uſe water colours for this purpoſe: the blue may be that of Pruſſia, and very bright; the

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paſte on one of the glaſſes five pieces of the red paper, one of which muſt cover the whole glaſs, the ſecond only the four lower diviſions, the third the three lower, the fourth the two loweſt, and the fifth the laſt diviſion only. On the other two glaſſes five pieces of the blue and yellow papers muſt be paſted in like manner.

You muſt alſo have a box of about ſix inches long, and the ſame depth and width as the glaſſes: it muſt be black on the inſide: let one end be quite open, and in the oppoſite end there muſt be a hole large enough to ſee the glaſſes completely. It muſt alſo open at the top, that the glaſſes may be placed in it conveniently.

When you have put any one of theſe glaſſes in the box, and the open end is

the red, carmine; and the yellow, gamboge mixed with a little ſaffron. Theſe colours muſt be laid very light and even, on both ſides of the paper.

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turned toward the ſun, you will ſee five diſtinct ſhades of the colour it contains.

If you place the blue and yellow glaſſes together, in a ſimilar direction, you will ſee five ſhades of green diſtinctly formed. When the blue and red glaſſes are placed, a bright violet will be produced; and by the red and yellow the ſeveral ſhades of orange.

If, inſtead of placing theſe glaſſes in a ſimilar poſition, you place the ſide A B of the yellow glaſs, againſt the ſide B D of the blue, (Plate XIII. Fig. 3.) you will ſee all the various greens that are produced by nature*; if the blue and red glaſſes be placed in that manner, you will have all the poſſible varieties of purples, violets, &c. and laſtly, if the red and orange

* In the firſt poſition of the glaſſes the quantity of blue and yellow being equal, the ſame ſort of green was conſtantly viſible: but by thus inverting the glaſſes, the quantity of the colours being conſtantly unequal, a very pleaſing variety of tints is produced.

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glaſſes be ſo placed, there will be all the intermediate colours, as the marygold, aurora, &c.

RECREATION XXXVI.

By means of the three primary colours, red, yellow, and blue, together with light and ſhade, to produce all the gradations of the priſmatic colours.

ON ſeven ſquare panes of glaſs paſte papers that are painted with the ſeven priſmatic colours, in the ſame manner as in the laſt Recreation. The colours for the orange, green, indigo, and violet, may be made by mixing the other three. Then with biſtre*, well diluted, ſhade a ſheet of very thin paper, by laying it light on both its ſides. With pieces of this paper cover four-fifths of a glaſs, of the ſame ſize with the others, by laying one piece on the four loweſt diviſions, another on

* The biſtre here uſed muſt be made of ſoot, not that in ſtone.

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the three loweſt, a third on the two loweſt, and the fourth on the loweſt diviſion only: and leaving the top diviſion quite uncovered.

When one of the coloured glaſſes is placed in the box, together with the glaſs of ſhades, ſo that the ſide A B of the one be applied to the ſide BD of the other, as in Fig. 3. of the laſt Recreation, the ſeveral gradations of colours will appear ſhaded in the ſame manner as a drapery judiciouſly painted with that colour.

It is on this principle that certain French artiſts have proceeded in their endeavours to imitate, by deſigns printed in colours, paintings in oil: which they do by four plates of the ſame ſize, on each of which is engraved the ſame deſign. One of theſe contains all the ſhades that are to be repreſented, and which are painted either black, or with a dark grey. One of the three other plates is coloured with blue, another

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another with red, and the third with yellow: each of them being engraved in thoſe parts only which are to repreſent that colour*, and the engraving is either ſtronger or weaker, in proportion to the tone of colour that is to be repreſented †.

Theſe four plates are then paſſed alternately under the preſs, and the mixture of their colours produces a print that bears

* When a red drapery is required, it is engraved on the plate aſſigned to that colour; and ſo of yellow and blue: but if one of the other colours be wanting, ſuppoſe violet, it muſt be engraved on thoſe that print the red and blue: and ſo of the reſt. The plates of this kind have been hitherto engraved in the manner of mezzotinto, but theſe, unleſs they are ſkilfully managed, ſoon become ſmutty. Engravings in the manner of the crayon, would perhaps anſwer better.

† The principal difficulty in this ſort of engraving ariſes from want of a ſkilful management, in giving each plate that preciſe degree of engraving which will produce the tone of colour required. If a bright green is to be repreſented, there ſhould be an equal quantity of graving on the red and yellow plates: but if an olive green, the yellow plate ſhould be engraved much deeper than the red

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no ſmall reſemblance to a painting. It muſt be confeſſed, however, that what has been hitherto done of this kind, falls far ſhort of that degree of perfection, of which this art appears ſuſceptible. If they who engrave the beſt in the manner of the crayon, were to apply themſelves to this art, there is reaſon to expect they would produce far more finiſhed pieces than we have hitherto ſeen.

RECREATION XXXVII.

The magical priſm.

MAKE a hole in the window-ſhutter of a dark room, through which a broad beam of light may paſs, that is to be refracted by the large glaſs priſm A B C, (Plate XIII. Fig. 4.) which may be made of pieces of mirrors cemented together, and filled with water.

Provide another priſm D E F, made of three pieces of wood: through the middle of

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of this there muſt paſs an axis on which it is to revolve. This priſm muſt be covered with white paper, and each of its ſides cut through in ſeveral places, ſo as to repreſent different figures, and thoſe of each ſide ſhould likewiſe be different. The inſide of this priſm is to be hollow, and made quite black, that it may not reflect any of the light that paſſes through the ſides into it.

When this priſm is placed near to that of glaſs, as in the figure, with one of its ſides E F, perpendicular to the ray of light, the figures on that ſide will appear perfectly white: but when it comes into the poſition *g h*, the figures will appear yellow and red, and when it is in the poſition *k l*, they will appear blue and violet. As the priſm is turned round its axis, the other ſides will have a ſimilar appearance. If inſtead of a priſm a four or five-ſided figure be here uſed, the appearances will be ſtill farther diverſified.

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This phenomenon ariſes from the different refrangibility of the rays of light. For when the ſide E F is in the poſition *g h*, it is more ſtrongly illuminated by the leaſt refrangible rays, and wherever they are predominant, the object will appear red or yellow. But when it is on the poſition *k l*, the more refrangible rays being then predominant, it will appear tinged with blue and violet.

RECREATION XXXVIII.

The ſolar magic lantern.

PROCURE a box, of about a foot high and eighteen inches wide, or ſuch other ſimilar dimenſions as you ſhall think fit; and about three inches deep. Two of the oppoſite ſides of this box muſt be quite open, and in each of the other ſides let there be a groove, wide enough to paſs a ſtiff paper or paſteboard. This box muſt be faſtened againſt a window on which the ſun's rays fall direct. The reſt of the window

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dow ſhould be cloſed up, that no light may enter.

Provide ſeveral ſheets of ſtiff paper, which muſt be blacked on one ſide. On theſe papers cut out ſuch figures as you ſhall think proper, and placing them alternately in the grooves of the box, with their blacked ſides towards you, look at them through a large and clear glaſs priſm; and if the light be ſtrong, they will appear to be painted with the moſt lively colours in nature. If you cut on one of theſe papers the form of the rainbow, about three quarters of an inch wide, you will have a lively repreſentation of that in the atmoſphere.

This Recreation may be farther diverſified, by paſting very thin papers, lightly painted with different colours, over ſome of the parts that are cut out: which will appear to change their colours, when viewed through the priſm, and to ſtand out from

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from the paper, at different diſtances, according to the different degrees of refrangibility, of the colours with which they are painted.

For greater convenience, the priſm may be placed in a ſtand on a table, at the height of your eye, and made to turn round on an axis, that when you have got an agreeable proſpect, you may fix it in that poſition. This experiment may be made at a trifling expence; and, if properly conducted, will afford no ſmall entertainment.

RECREATION XXXIX.

The artificial rainbow.

OPPOSITE a window into which the ſun ſhines direct, ſuſpend a glaſs globe filled with water, by a ſtring that runs over a pulley, ſo that the ſun's rays may fall on it. Then drawing the globe gradually up, when it comes to the height of

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of about forty degrees* you will see, by placing yourself in a proper situation, a purple colour in the glass, and by drawing it gradually up higher, the other prismatic colours, blue, green, yellow, and red, will successively appear; after which the colours will disappear, till the globe is raised to about fifty degrees, when they will again be seen, but in an inverted order, the red appearing first, and the blue or violet last: and when the globe comes up to little more than fifty-four degrees they will totally vanish.

These appearances serve to explain the phenomena of natural rainbows, of which there are frequently two; the one being about eight degrees above the other, and the order of their colours is inverted, as

* That is if you suppose an arch of a circle to be drawn from the horizon to the zenith, and divided into ninety equal parts or degrees, the globe must be raised to the height of forty of those degrees.

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in this experiment, red being the uppermoſt colour in the lower bow, and violet in the other.

The rainbow is not in the clouds, but in the falling rain, and always oppoſite the ſun. The different order of the colours in the bows ariſes from their different reflections; thoſe of the under bow being cauſed by two refractions and one reflection, and thoſe of the upper, by two refractions and two reflections, and therefore the colours of this are leſs bright than the other, their ſtrength being diminiſhed by every reflection.

Now, it has been proved by repeated experiments, that forty degrees forms the greateſt angle by which the moſt refrangible rays can, after one reflection, be refracted to the eye; and that ſomething more than forty-two degrees forms the greateſt angle, under which the leaſt refrangible rays can come to the eye after one

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one reflection. Therefore all the colours of the lower bow muſt lie in the ſpace of leſs than two degrees. In like manner it has been proved, that fifty degrees make the leaſt angle under which the leaſt refrangible rays can be viſib'e to the eye after two reflections; and that about fifty-four degrees will be the leaſt angle under which the moſt refrangible rays can come to the eye after two reflections. Therefore all the colours of the upper bow muſt be in leſs than four degrees.

It follows from what is here ſaid, that all rainbows are of a circular form and equal magnitude, and as they are always oppoſite the ſun, the parts we ſee of them muſt be in proportion to his height above the horizon: when his altitude is forty degrees, only the upper rainbow can be viſible, and when it is fifty-four degrees there can be no rainbow: but as the ſun's height, during the winter half year, is never equal to forty degrees, there may then be always two bows viſible.

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RECREATION XL.

The prismatic camera obscura.

MAKE two holes F, *f*, (Plate XIII. Fig. 5.) in the shutter of a dark chamber, near to each other, and against each hole place a prism A B C, and *a b c*, in a perpendicular direction, that their spectrums N M may be cast on the paper in a horizontal line, and coincide with each other; the red and violet of the one being in the same part with those of the other. The paper should be placed at such a distance from the prisms that the spectrum may be sufficiently dilated.

Provide several papers nearly of the same dimension with the spectrum, cross these papers, and draw lines parallel to the divisions of the colours. In these divisions cut out such figures as you shall find will have an agreeable effect, as flowers, trees, animals, &c.

When

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When you have placed one of these papers in its proper position, hang a black cloth or paper behind it, that none of the rays that pass through may be reflected, and confuse the phenomenon. The figures cut on the paper will then appear strongly illuminated with all the original colours of nature.

If while one of the prisms remains at rest, the other be revolved on its axis, the continually alteration of the colours will afford a pleasing variety; which may be farther increased by turning the prism round in different directions.

When the prisms are so placed that the two spectrums become coincident in an inverted order of their colours, the red end of one falling on the violet end of the other, if they be then viewed through a third prism D H, held parallel to their length, they will no longer appear coincident, but in the form of two distinct spectrums,

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ſpectrums, *p t*, *n m*, (Fig. 6.) croſſing one another in the middle, like the letter X. The red of one ſpectrum and the violet of the other, which were coincident at N M, being parted from each other by a greater refraction of the violet to *p* and *m*, than that of the red to *n* and *t*.

This Recreation may be farther diverſified by adding two other priſms, that ſhall form a ſpectrum in the ſame line, and contiguous to the other; by which not only the variety of figures, but the viciſſitude of colours will be conſiderably augmented.

RECREATION XLI.

The diatonic ſcale of colours.

THE illuſtrious Newton, in the courſe of his ſagacious inveſtigations of the properties of light, diſcovered that the length of the ſpaces which the ſeven primary colours poſſeſs in the ſpectrum, exactly correſponds to thoſe of chords that

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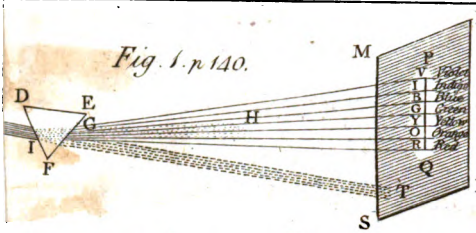

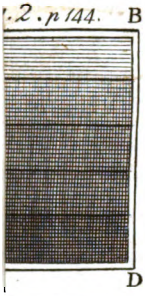

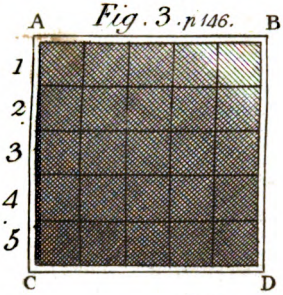

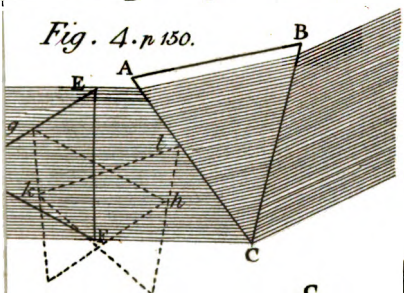

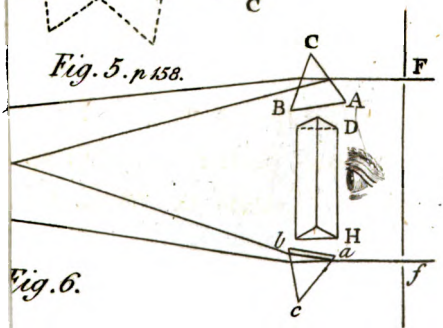

Fig. 6.

J. Lodge Sculp.

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that ſound the ſeven notes in the diatonic ſcale of muſic. As is evident by the following experiment.

On a paper in a dark chamber let a ray of light be largely refracted into the ſpectrum AFTMGP, (Plate XIV. Fig. 1.) and mark the preciſe boundaries of the ſeveral colours, as *a*, *b*, *c*, &c. Draw lines from thoſe points perpendicular to the oppoſite ſide, and you will find that the ſpaces M *r f* F, by which the red is bounded; *q p d e*, by which the orange is bounded; *p o c d*, by which the yellow is bounded, &c. will be in exact proportion to the diviſions of a muſical chord for the notes of an octave, that is, as the intervals of theſe numbers 1, $\frac{8}{9}$, $\frac{5}{6}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{9}{16}$, $\frac{1}{2}$.

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RECREATION XLII.

Colorific muſic.

FATHER Caſtel, a Frenchman, in a curious book he has publiſhed on Chromatics, ſuppoſes the note *ut* to anſwer to blue in the priſmatic colours, the note *re* to yellow, and *mi* to red. The other tones he refers to the intermediate colours, from whence he conſtructs the following gamut of colorific muſic.

Ut	Blue
Ut ſharp	Sea-green
Re	Bright green
Re ſharp	Olive green
Mi	Yellow
Fa	Aurora
Fa ſharp	Orange
Sol	Red
Sol ſharp	Crimſon
La	Violet
La ſharp	Blue violet
Si	Sky blue
Ut	Blue

This gamut, according to his plan, is to be continued in the ſame manner for the fol-

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following octave; except that the colours are to be more vivid.

He ſuppoſes that theſe colours by ſtriking the eye in the ſame ſucceſſion as the ſounds, to which he makes them analogous, do the ear, and in the ſame order of time, they will produce a correſpondent ſenſation of pleaſure in the mind. It is on theſe general principles, which F. Caſtel has ingeniouſly dilucidated in his treatiſe, that he has endeavoured, through with little ſucceſs, to eſtabliſh his ocular harpſichord.

The conſtruction of this inſtrument, as here explained, will ſhow that the effects produced by colours by no means anſwer thoſe of ſounds, and that the principle relation there is between them, conſiſts in the duration of the time that they reſpectively affect the ſenſes.

Between two circles of paſteboard, of ten inches diameter, A B and C D (Plate

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XIV. Fig. 2.) encloſe a hollow paſteboard cylinder E, eighteen inches long. Divide this cylinder into ſpaces half an inch wide, by a ſpiral line that runs round it from top to bottom, and divide its ſurface into ſix equal parts by parallel lines drawn between its two extremities; as is expreſſed in the figure.

Let the circle A B, at top, be open, and let that at bottom, CD, be cloſed, and ſupported by an axis or ſcrew, of half an inch diameter, which muſt turn freely in a nut placed at the bottom of a box we ſhall preſently deſcribe. To the axis juſt mentioned adjuſt a wooden wheel G, of two inches and a half in diameter, and that has twelve or fifteen teeth, which take the endleſs ſcrew H. Let this cylinder be incloſed in a box ILMN (Fig. 3.) whoſe baſe is ſquare, and at whoſe bottom there is a nut, in which the axis F turns. Obſerve, that the endleſs ſcrew H, ſhould come out of the box, that it may receive

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the handle O, by which the cylinder is to be turned.

This box being closed all round, place over it a tin covering, which must be perforated in different parts; from this cover there must hang three or four lights, so placed that they may strongly illumine the inside of the cylinder, In one side of this box (which should be covered with pasteboard) cut eight apertures of half an inch wide, and one-third of an inch high; they must be directly over each other, and and the distance between them must be exactly two inches. It is by these openings, which here correspond to the musical notes, that the various colours analogous to them, are to appear; and which being placed on the pasteboard cylinder, as we have shown, are reflected by means of the lights placed within it.

It is easy to conceive, that when the handle O is turned, the cylinder in consequence

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ſequence riſing half an inch, if it be turned five times round, it will ſucceſſively ſhow, at the openings made in the ſide of the box all thoſe that are in the cylinder itſelf, and which are ranged according to the direction of the inclined lines drawn on it. It is therefore according to the duration of the notes which are to be expreſſed, that the apertures on the cylinder are to be cut. Obſerve that the ſpace between two of the parallel lines drawn vertically on the cylinder, is equal to one meaſure of time, therefore for every turn of the cylinder, there are ſix meaſures, and thirty meaſures for the air that is to be played by this inſtrument.

The ſeveral apertures being made in the ſide of the cylinder, in conformity to the notes of the tune that is to be expreſſed, they are to be covered with double pieces of very thin paper, painted on both ſides with the colours that are to repreſent the muſical notes.

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Fig. 1. p 161.

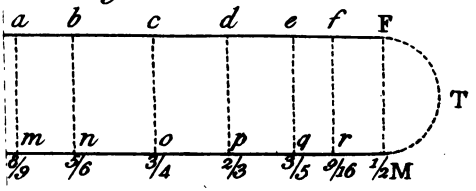
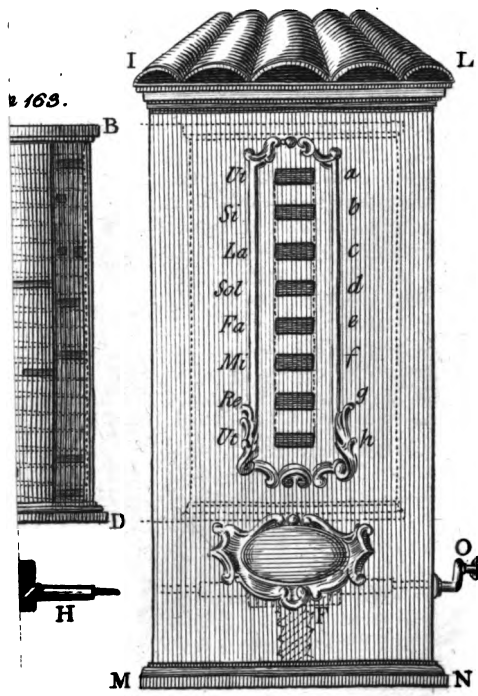


Fig. 3. p 164.



J. Ludgo Sculp.

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This Recreation might be executed in a different manner, and with a much greater extent; but as the entertainment would not equal the trouble and expence, we have thought it ſufficient to give the above piece, by which the reader will be enabled to judge how far the analogy ſuppoſed by F. Caſtel really exiſts.

This article is taken from M. Guyot, who, though he commends the good father's ingenuity and induſtry, attributes but little merit to his ſcheme. Not having ſeen F. Caſtel's book, we cannot pretend to judge of the merit of his plan. It is evident, however, from the foregoing Recreation, that there is a much ſtronger relation between ſounds and colours than M. Guyot ſeems to imagine.

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PERSPECTIVE RECREATIONS.

If the following Recreations do not directly belong to optics, they have ſo great a reſemblance to it, that perhaps they could not be introduced any where elſe with ſo much propriety.

ANAMORPHOSES.

RECREATION XLIII.

To draw on a plane ſurface an irregular figure, which, when ſeen from a proper point of view, will appear exactly ſimilar to a given figure.

ON a paper or paſteboard draw the parallelogram ABCD (Pl. XV. Fig. 1.) of what ſize you pleaſe, provided the ſides AB and CD be longer than AC and BD; let it be, for example, four inches long and three wide. Divide it into twelve equal parts, and each of thoſe into four other

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other equal parts*. On this parallelogram draw the regular figure that you would have repreſented, in a diſtorted form, on the plane.

Draw on a paper the line B A (Fig. 2.) indefinite toward A. Directly over the point B, mark the point of view C, and let fall the perpendicular C B On the line A B mark the point C, and draw from the point of view C, to that point D, the line C D. On the ſame line, and at a convenient diſtance from the point C, draw the line F G, of the ſame length with A C (Fig. 1.) let it be perpendicular to the line C D, and by which it muſt be biſected. From the point C to F and G, draw the two lines C F and C G, and continue them till they meet the line A B at the points H and O.

* The ſmaller the diviſions are, the more eaſy it will be to repreſent the ſubject with preciſion.

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The line H O will then appear to the eye C of the ſame dimenſion with the line F G, which is equal to the width of the parallelogram ABCD, as muſt neceſſarily follow from the principle laid down in the part of Optics; that is, becauſe both theſe lines appear under the ſame angle H C O.

Then divide the line F G into the ſame number of parts with the ſide of the parallelogram A C, (Fig. 1.) and from the point of view C, to the line A B, draw the lines C I, C L, C M, C N, through the diviſions in the line F G.

On another paper draw the line A B (Fig. 3.) equal to the line C A, (Fig. 2.) and at its extremity B, erect the indefinite perpendicular B C. From the point B of the line A B to the point E, in the ſame line, ſet off a ſpace equal to the line C F, (Fig. 2.) At the point E, divide the line A B by the perpendicular H I, equal to C D,

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C D, (Fig. 1,) that is, equal to the length of the parallelogram. This line muſt alſo be divided into two equal parts by the line A B.

From the point B to the points H and I, draw the lines B H and B I, and continue them towards C and D. Take the diſtances that are between H and I, L D, M and N, (Fig. 2.) and tranſpoſe them to the line A B (Fig. 3.) from A to I, L, M, N, O, and draw the lines Y, Z, perpendicular to each of theſe diviſions. Divide the line C D into eight equal parts, and draw the lines B G, B Q, B R, B S, B T, and B V.

Theſe diviſions being made, the trapezium CHDI will be divided into as many parts as the parallelogram ABCD, (Fig. 1.) and all theſe diviſions, though of themſelves irregular, will appear to the eye, when placed at the point C, (Fig. 2.) of the

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ſame figure and magnitude as the parallelogram : all the lines that form the diviſions included in the trapezium C H D I being ſeen under ſimilar angles. In order to facilitate the tranſpoſing the ſeveral parts of the deſign contained in the parallelogram, to the trapezium, it will be proper to number the principal diviſions. The whole, moreover, ſhould be traced with great preciſion*. Obſerve, that all the right lines in the parallelogram form as many right lines in the trapezium, therefore when you have marked their extremities, you may draw them with a ruler from one point to the other. With regard to curve lines, you will judge of their direction by the points where they cut the diviſions of the parallelograms, and tranſ-

* This method of drawing an irregular figure is taken from M. Guyot, and differs from thoſe that are given by Niceron and Ozanam, as it appears more exact to place the deſign that is to be repreſented in ſuch manner that the ray, or principal point of view, may fall perpendicular on the center of the ſuppoſed picture placed at F G.

poſe

poſe them to the correſponding diviſions of the trapezium.

Note, care muſt be taken that the paper on which the diſtorted figure is drawn be well ſtretched on a plane, that its ſurface may be quite even. You ſhould alſo examine it attentively from the point of view; and for that purpoſe it will be convenient to have a little circle of braſs, through which a hole of about two tenths of an inch is made, and placed upon a ſtand (ſee Fig. 4.) By that overture this piece of perſpective illuſion will produce an agreeable ſurprize.

Obſerve that the diſtance of the point of view from the picture may be taken at pleaſure, provided it be not leſs than its witdh. When the point of view is near the picture it appears more deformed than when it is at a greater diſtance, for the parts then become more extended toward C D; from whence it follows, that if we would

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would execute a deſign of this ſort on the ſide of a gallery, it muſt be regulated according to the dimenſions of the part on which it is to be drawn. Theſe ſubjects, when well executed, at full length, are highly agreeable, and appear the more extraordinary, as the eye not being able to view them but by parts, (when walking in the gallery*) we cannot form the leaſt idea of what they will preſent when ſeen from a proper point of view, where the effect is truly admirable.

* There are, at the convent of Minims in the Place Royale at Paris, ſeveral ſubjects of this kind, painted on the walls of the cloiſter by P. Niceron, who has publiſhed an excellent treatiſe on this art. Among others, the figure of a Magdalen daily excites the curioſity of a number of connoiſſeurs. Unfortunately, theſe pieces, which have ſuffered by time, have not been properly repaired.

RECRE-

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Fig. 1. p. 168.

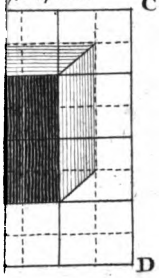


Fig. 4. p. 173.

Fig. 2. p. 169.

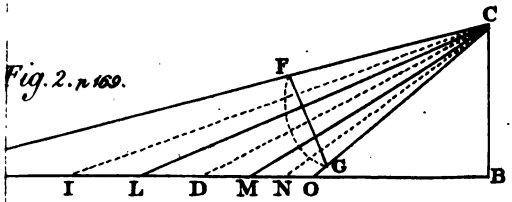
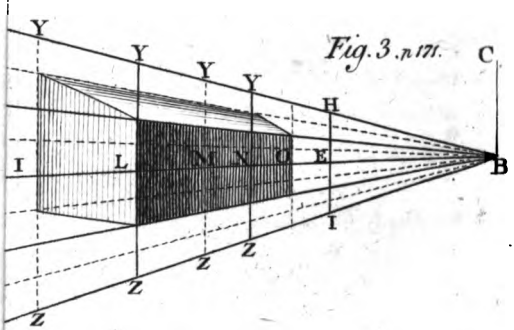


Fig. 3. p. 171.



J. Lodge Sculp.

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RECREATION XLIV.

To draw an irregular figure on a plane, which being seen from two oppoſite points of view, ſhall repreſent two different regular objects.

MAKE choice of a plane of convenient ſize, ſuppoſe two feet long and half a foot wide. Draw the line A B of the ſame length, (Plate XVI. Fig. 1.) continue it on each ſide to C and D, and erect the perpendiculars C F and D G to the height of about three inches. Draw the lines A F and B G, and divide the line A B into ſix equal parts at the points S, or into any other number you ſhall think fit. From the two points of view F and G draw the lines F S and G S, to thoſe ſix diviſions.

Then on the line G A ſet off the diſtance G B, and on the line F B the diſtance F A, and draw the two lines B H and A I, which will determine the width of the two ſubjects

jects you are to represent on the plane, and are to be viewed, the one from the point F, and the other from G; and of which the unequal divisions formed by the lines GS and FS, will determine those that are to correspond to the separate and inclined parts of the irregular figure which is to be seen from the points of view F and G.

This first preparation being made, draw the parallelogram ABCD (Fig. 2.) of the same length with the line A B in the preceding figure, and about six inches wide: divide it into two equal parts by the line F G, which continue to H and I, equal to the distance there is between C A and D B (Fig. 1.)

From the points AOSB (Fig. 1.) let fall the perpendiculars AA, OL, SL, and BC, on the line A C (Fig. 2.) and from the points L draw the lines L M parallel to A B.

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From the four angles of the parallelogram ABCD, draw the lines A I and B I to the point of view I, and thoſe of C H and D H to the other point of view H; theſe lines will determine by the ſections at X and Y the apparent height of the figure.

Then divide the lines A B and CD, into as many equal parts as you ſhall think proper, and from thoſe points draw the lines N I and N H.

Next, draw on a paper the two parallelograms FGHI, LMNO, (Fig. 3.) and on them you are to draw the two different deſigns that you would repreſent in the diſtorted figure. Let each of theſe parallelograms be of an equal height with the diſtance X Y, (Fig. 2.) and of the ſame length as H B (Fig. 1.) Divide their height FH or LN, according to the diviſions of the line XY (Fig. 2.) and their length H I or N O, according to thoſe of the line B H (Fig. 1.)

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After having drawn the two deſigns, as correctly as poſſible, on the diviſions juſt mentioned, take a board or paſteboard ABCD (Fig. 4.) of the ſame dimenſions with the parallelogram ABCD, (Fig. 2.) and on it draw the lines L M, correſponding to the perpendiculars let fall from OS. (Fig. 1.) Theſe lines ſhould be drawn ſufficiently deep to admit the folds of paper hereafter mentioned.

Take a very thin paper ABCD (Fig. 5.) of about two feet and a half long, and ſix inches wide, and on it draw parallel lines, at diſtances correſponding to A O, O S, S O, &c. (Fig. 1.) which you will meaſure with a compaſs from the angles on the line A B (Fig. 1.)

Divide this paper into two equal parts by a line drawn from the points X and Y, and obſerve that it is on the ſpaces *b*, *b*, *b*, &c. that you are to draw the irregular figure which is to be ſeen from the point F;

and

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and on thoſe of *c*, *c*, *c*, &c. that which is to be ſeen from the point G.

On each of theſe ſpaces draw the lines, not punctuated, of the parallelogram A B C D (Fig. 2.) that terminate in the points H and I. Then trace on the ſame paper all the ſtrokes of the two figures drawn on the two parallelograms, (Fig. 3.) carefully obſerving the ſeveral diviſions to which they correſpond.

When this irregular figure is quite finiſhed, fold the paper according to the diviſions that have been drawn on it, ſo that each of the diviſions S, may turn one way, and each of the diviſions O, the other way; and paſte the whole on a board, in ſuch a manner that the folds made on the blank ſide of the paper, may anſwer to the lines traced in the board. On the paper thus paſted lay ſomething that may keep it in proper form till the paſte is dry. Then let it be ſo placed that ſix of its diviſions

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may be oppoſite to each of the points of view F and G.

To diſtinguiſh the objects on the parallelogram with greater preciſion, you muſt have (as in the foregoing Recreation) two little circles, with a ſmall hole in each, and place them exactly on the points of view that have been fixed. The eye being then placed at either of thoſe points, will diſcern the regular figure; but when the ſcheme is viewed in front, it preſents a form ſo diſtorted, that it is impoſſible to conjecture what it is intended to repreſent.

Obſerve, This deſign differs in the conſtruction from that in the firſt Recreation; as here, the diviſions drawn on the irregular figure regulate thoſe of the two other figures. It is indeed more difficult, but then it is alſo more entertaining; and with a little application it may be eaſily executed, as nothing more is neceſſary than to

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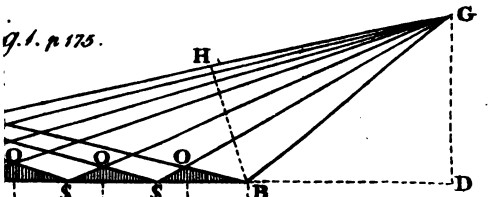
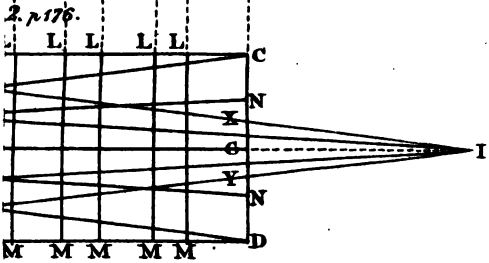
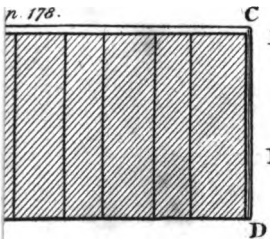


g. 1. p 175.



2. p 176.



p. 178.

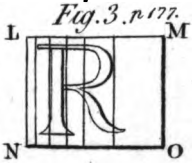
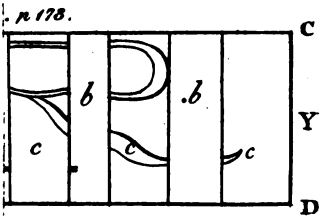


Fig. 3. p 177.



p 178.

S. Sidgwick sculp

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to transfer the diviſions carefully from one figure to the other.

To perform this ſort of anamorphoſis with more celerity, you may draw the plan on a paſteboard, and placing a tranſparent paper over it, trace the ſubject thereon: the ſame paſteboard will ſerve to execute, equally well, all ſorts of ſubjects.

RECREATION XLV.

To draw on the baſe of a cone, an irregular figure, which ſhall appear, when ſeen from a proper point of view, not only regular, but elevated above the ſurface of the cone.

THE geometric method that might be here given for drawing the figure propoſed, being extremely tedious and difficult, on account of the various curves that it is neceſſary to draw on the baſe of the cone, we ſhall here deſcribe a more ſimple method, by making uſe of a lamp. This method may likewiſe be uſed in the

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drawing diſtorted ſubjects on all irregular ſurfaces, whatever their figure may be.

Let E F G (Plate XVII. Fig. 1.) be the cone, on the baſis of which a diſtorted figure is to be drawn, that being viewed from the point H, ſhall appear regular, and exactly reſembling that which is placed at N M. Place the cone in a circular overture made in the board A B C D, which ſhould be ſupported by four feet, that the point of the cone may not touch the table on which it ſtands. Fix at the end of the board an upright piece I, that is to hold a ſmall circle of braſs, through, which is made a hole H, of two tenths of an inch in diameter, that ſerves for the point of view.

Prepare a lamp as A, (Fig. 2.) the light of which may be raiſed or lowered at pleaſure, and to which is fixed a braſs arm B C, bearing a ſort of funnel D, in the ſhape of a truncated cone, and whoſe opening

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ing at the end next the light is not more than three or four tenths of an inch in diameter.

Draw the ſubject you would repreſent on the baſe of the cone, on a piece of glaſs of equal height with the ſpace M N*, that is, of the apparent height of the diameter E F, of the baſe of the cone when ſeen from the point H: place it perpendicular on the board at the point F, that is, at the extremity of the cone.

Theſe preparations being made, take away the piece that bears the point of view H, and place the lamp, ſo prepared, in ſuch manner that the light may be exactly where they point H was. Its rays then paſſing through the glaſs at M N, will en-

* It muſt be drawn with a very light ſtroke, and you muſt make uſe of a colour that is quite opaque.

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lighten all the lower ſurface of the cone, and there ſhow, in a diſtorted form, the ſubject that is painted on the glaſs.

Then draw with a pencil all the ſtrokes of the ſhadow that are on the cone; and taking away the light, place the point of view H, and ſee if what you have drawn correſpond with the ſubject on the glaſs, correcting what imperfections there may chance to be. In the laſt place, colour the ſubject ſo traced on the cone, with the utmoſt attention, inſpecting your work from time to time from the point of view, before you give it the finiſhing ſtrokes.

When the figure that is drawn and painted on the baſe of the cone is viewed from the point H, it appears to be at the ſame point where the glaſs M N was placed, and in the ſame form that it was painted on that glaſs. The eye even perceives it above the ſurface of the board in which the cone is placed, and

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and thereby receives a remarkable and pleaſing illuſion.

Note. This manner of drawing diſtorted figures by means of a lamp and tranſparent glaſs, may be advantageouſly uſed for all irregular figures, that are difficult to draw geometrically. The ſubjects that are drawn on the glaſs may alſo be ſhaded and coloured, in the ſame manner as for the camera obſcura; in order to have the appearance of colours on the diſtorted picture.

If a circle be deſcribed on paper or paſteboard, and placed firm upon the table, where the cone is ſuppoſed to be, it will have preciſely the ſame effect.

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RECREATION XLVI.

To draw, eaſily and correctly, a landſcape or any other object, without being obliged to obſerve the rules of perſpective, and without the aid of the camera obſcura.

PROCURE a box of paſteboard ABCD (Plate XVII. Fig. 3.) of about a foot and a half long, and made in the ſhape of a truncated pyramid, whoſe baſe B D F G is eight inches wide, and ſix inches high. Fix to the other end of it a tube of four or five inches long, and which you can draw out from the box more or leſs. Line the inſide of the box with black paper, and place it upon a leg or ſtand of wood H, and on which it may be elevated or depreſſed by the hinge I.

Take a ſmall frame of wood A B C D (Fig. 4.) and divide it at every inch by lines of black ſilk drawn croſs it, forming forty-eight

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ty-eight equal parts; divide these into still smaller equal parts, by lines of finer silk*; fix this frame at the end B D, as the base of the pyramid.

Provide a drawing paper, divided into the same number of parts as is the frame, by lines lightly drawn in chalk. It is not material of what size these divisions are; that will depend entirely on the size you propose to draw the objects by this instrument.

Place this instrument opposite a landscape, or any other object that you want to draw, and fix the leg firmly on, or in the ground, that it may not shake: then turning it to the side you choose, raise or incline it, and put the tube farther in or out, till you have gained an advantageous view of the object you intend to draw.

* The different size of the silk serves to distinguish more readily the corresponding divisions.

Place

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Place yourſelf by the inſtrument *, which you have adjuſted to the height of your eye, and looking through the tube, carefully obſerve all that is contained in each diviſion of the frame, and tranſpoſe it to the correſponding diviſion in your paper: and if you have the leaſt knowledge in painting, or even drawing, you will make a very pleaſing picture, and one in which all the objects will appear in the moſt exact proportion.

Note, by the ſame method you may draw all ſorts of objects, as architecture, views, &c. and even human figures, if they remain ſome time in the ſame attitude, and are at a proper diſtance from the inſtrument.

* You may provide yourſelf with one of thoſe ſtools that fold up, and are eaſily portable.

RECRE-

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RECREATION XLVII.

Illuminated proſpects.

PROVIDE yourſelf with ſome of thoſe prints that are commonly uſed in optical machines, printed on very white and very thin paper; taking care to make choice of ſuch as have the greateſt effect from the manner in which the objects are placed in perſpective. Paſte one of theſe on the borders of a frame, and paint it carefully with the moſt lively colours, making uſe of none that are terreſtrial. Obſerve to retouch thoſe parts ſeveral times where the engraving is ſtrongeſt*, then cut off the upper part or ſky, and fix that on another frame.

The prints being thus prepared, place them in a box ABCD (Plate XVII. Fig. 5.)

* When you colour a print, place it againſt a plate of glaſs, in an erect poſition before you, that it may be enlightened by the ſun. You may alſo colour both ſides of the print.

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the opening to which EFGH, ſhould be a little leſs than the print. Cover this opening with a glaſs, and paint all the ſpace between it and the prints, which ſhould be about two or three inches, black. The frame that contains the ſky ſhould be about an inch behind the other. In the back part of this box, which is behind the prints, and which may be about four inches deep, place four or five ſmall candleſticks to hold wax lights, and cover that part entirely with tin, that it may be the more luminous.

When the print is placed between the wax lights and the opening in the front of the box, and there is no other light in the room, the effect will be highly pleaſing; eſpecially if the lights are at a ſufficient diſtance from each other, and not too ſtrong, that they may not occaſion any blots in the print. Thoſe print that repreſent the riſing or ſetting of the ſun will have a very pictureſque appearance.

Such

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Fig. 1. p 182.

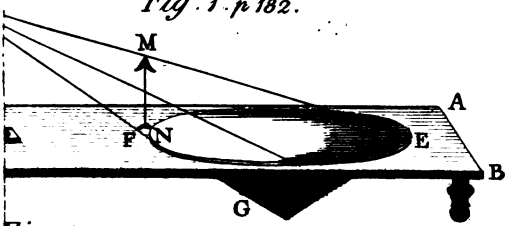


Fig. 4. p 186.

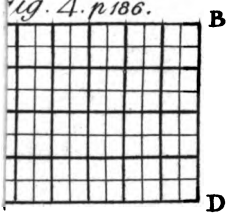
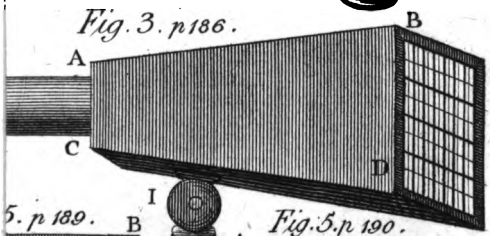


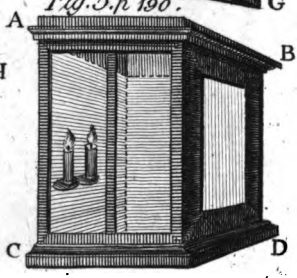
Fig. 2. p 182.

Fig. 3. p 186.



5. p 189.

Fig. 5. p 190.



J. Ledge Sculp.

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Such as repreſent conflagrations have alſo a ſtriking effect.

Note. There ſhould be two grooves for the print next the glaſs, that you may inſert a ſecond ſubject before you draw away the firſt: and that the lights in the back of the box may not be diſcovered.

You muſt not, thinking to make the print more tranſparent, cover it with varniſh; for that will prevent the degradation of the colours from being viſible. The frame ſhould enter the ſide of the box by a groove, that a variety of ſubjects may be introduced.

RECREATION XLVIII.

Tranſparent illuminations.

THE box that is to encloſe theſe ſubjects may be made in the ſame manner with that of the preceding Recreation, only obſerving that it will be proper to augment

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ment the number of lights, and employ ſuch prints as are agreeable to the ſubject.

With a very ſmall circular tool you are to cut out all the places where the light is intended to appear, or where it is expreſſed, if the print repreſent an illumination. Particular care muſt be had to make uſe of the fineſt tools in thoſe parts of the print that are intended to appear at the greateſt diſtance.

Theſe prints muſt by no means be tranſparent, like thoſe in the preceding Recreation; on the contrary, they ſhould be printed on a thick paper, or rather it ſhould be doubled, that very little of the engraving may appear. Behind the print muſt be placed a very fine tranſparent paper, varniſhed, fixed on a frame, and lightly painted with a deep yellow, or ſaffron colour, which muſt be laid on thickeſt at thoſe places that are oppoſite the parts of the print that are to appear at the greateſt diſtance.

The

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The ſetting of the ſun, ſucceeded by a night ſcene, may be very pleaſingly repreſented in this method. Thus: procure a landſcape, in which is the figure of the ſetting ſun, illuminated as above deſcribed. Let the bottom of this ſcene reſt upon an upright board in the box, of about two or three inches high, and let it be gradually moved off that board, and lowered down to the bottom of the box, on the ſide next the glaſs, by which means the ſun will appear to deſcend. Let the lights then be gradually withdrawn: and change the firſt landſcape for a night ſcene, with the moon and ſtars, properly perforated. The yellow paper muſt be changed for one that is white and tranſparent, and the lights be again introduced, when the moon, ſtars, and other illuminated parts will appear in their natural form. For the more eaſy removing of the lights they may be all placed upon one ſtand, but at different diſtances.

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This piece of illumination might alſo be put into the common optical machine; but the magnifying glaſs there uſed conſiderably enlarging the objects, the light reflected by the cut and tranſparent parts, then becomes greatly weakened, as it takes up a much larger ſpace; and that greatly diminiſhes the vivacity which is neceſſary to imitate nature, and to produce the illuſion. If, however, you are deſirous of viewing this piece by the magnifier, you muſt take away the inclined mirror which is placed in thoſe ſort of optical machines, and place the tranſparent picture or print in the front of the glaſs; otherwiſe it will be ſcarce poſſible to render it luminous, except by reflection, which affords but a very feeble light.

ACOUS-

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ACOUSTICS.

THE ſcience of acouſtics inſtructs us in the nature of ſound. It is divided by ſome writers into diacouſtics, which explains the properties of thoſe ſounds that come directly from the ſonorous body to the ear; and catacouſtics, which treats of reflected ſounds: but ſuch diſtinction does not appear to be of any real utility.

DEFINITIONS.

1. Sounds are either acute or grave, ſimple or compound.

2. Thoſe ſounds that are ſhrill or ſharp are called acute: and

3. Thoſe that are deep or hollow, are called grave ſounds.

4. A ſimple ſound is that produced by a ſingle ſtroke on a ſonorous body; and compound ſounds are thoſe that proceed from ſeveral bodies ſtruck at the ſame time, or from ſeveral ſtrokes on different parts of the ſame body.

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5. A chord is a ſtring of catgut, braſs wire, &c. ſo ſtretched as when ſtruck to yield a diſtinct ſound.

6. A vibration is the regular, alternate motion of bodies, by which, when put out of their natural ſtate, they endeavour to return to it. Thus the ſtring A B (Pl. XVIII. Fig. 1.) being forced out of its natural poſition to that of A *c* B, vibrates to *d*, and then to *e*, *f*, *g*, &c. till it returns to its firſt ſtate at A B.

APHORISMS.

1. All ſound is produced by an undulatory or wavelike motion of the air*, excited by the vibrations of a ſonorous body proceeding from a ſtroke of ſome other body.

2. Acute ſounds ariſe from quick vibra-

* That air is the medium of ſound is evident from a bell placed in the receiver of an air-pump, which may be heard to a conſiderable diſtance before the air is exhauſted, but after, can ſcarce be diſtinguiſhed when quite near.

tions

tions of the parts of a body, and grave ſounds from ſlow vibrations.

3. Smooth and clear ſounds proceed from bodies that are homogeneous, and of an uniform figure; and harſh or obtuſe ſounds, from ſuch as are of a mixed matter and irregular figure.

4. In bodies of a ſimilar figure and dimenſion, and of equal elaſticity, their tones are in proportion to their denſities: the denſer the body the graver is the tone; therefore a bar of gold muſt have a graver ſound than one of ſilver, of equal dimenſions; ſuppoſing them to be of equal elaſticity.

5. If two bodies are compoſed of the ſame matter, and are of ſimilar figure, their tones will be in proportion to the quantities of matter. Thus, the tones of two globes of braſs will be to each other in proportion to their diameters.

6. The vibrations of chords is in proportion to their lengths, diameters, and tenſion.

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7. All the vibrations of the ſame chord, as A *c* B, (Plate XVIII. Fig. 1.) A *d* B, A *e* B, &c. are made in the ſame time.

8. If two chords are of the ſame diameter or thickneſs, and equally ſtretched, their vibrations, in the ſame time, will be in proportion to their lengths inverſely, that is, a chord of ſix inches will make two vibrations while a chord of twelve inches makes one*.

9. If two chords frequently vibrate together they produce a concord; and the more frequent the coincidence of vibration, the more pleaſing the concord.

10. Sound is propagated in concentric

* From hence we learn how to divide any chord ſo that it may ſound the ſeven concords; as thus, divide the line A B (Plate XVIII. Fig. 2.) into two equal parts in C, and C B into two equal parts at D, and C D into two equal parts at E. Then A C will be to A B as $\frac{1}{2}$, that is, an octave; A C to A D as $\frac{2}{3}$, a fifth; A D to A B as $\frac{3}{4}$, a fourth; A C to A E as $\frac{4}{5}$, a third greater; A E to A D as $\frac{5}{6}$, a third leſſer; E B to A E as $\frac{2}{5}$, a ſixth greater; and A E to A B as $\frac{5}{8}$, a ſixth leſſer.

circles

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circles every way round the ſonorous body*.

11. All ſounds, whether great or ſmall, are of equal velocity.

12. The ſpace paſſed over by ſound is conſtantly equal in equal times, whether it come from a greater or leſs diſtance.

13. The motion of ſound is at the rate of 1142 feet in a ſecond, and no obſtacles obſtruct its progreſs; a contrary wind only a ſmall matter diminiſhing its velocity†.

* The diſtance to which ſounds may be heard is very great. Authors of credit relate that the ſound of cannon has been heard 180 and 200 miles.

† By this axiom we are enabled to find the diſtance between objects that would be otherwiſe immeaſurable. For example, ſuppoſe you ſee the flaſh of a gun in the night at ſea, and tell ſeven ſeconds before you hear the report, it follows therefore, that the diſtance is ſeven times 1142 feet, that is twenty-four yards more than a mile and a half. In like manner if you obſerve the number of ſeconds between the lightning and the report of the thunder, you know the diſtance of the cloud from whence it proceeds.

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14. The velocity of ſound is to that of a briſk wind as fifty to one.

15. The ſtrength of ſounds is greateſt in cold and denſe air, and leaſt in that which is warm and rarefied.

16. In all ſounds the angle of incidence is equal to that of reflection, that is, if a line be drawn perpendicular to the reflecting ſurface, the point from which the ſound iſſues, and that to which it is reflected, will be equally diſtant from the perpendicular line.

RECRE-

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RECREATION XLIX.

The Æolipiles.

AN æolipile is a ſmall globe of braſs or other metal, into which a ſlender neck or pipe is inſerted. This ball, when made red hot, is caſt into a veſſel of water, which will ruſh into its cavity, then almoſt void of air. The ball being then ſet on the fire, the water, by the rarefaction of the internal air, will be forced out in ſteam, by fits, with great violence, and with a ſtrange noiſe.

If to the necks of two or more of theſe æolipiles there be fitted thoſe calls that are uſed by fowlers and hunters, and the æolipiles be then placed privately on the fire; as the ſteam ruſhes forth they will make ſuch a horrible noiſe, that a perſon who is ignorant of the contrivance cannot fail being greatly aſtoniſhing.

Great

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Great care ſhould be taken that the neck of the æolipile be not ſtopped when it is placed on the fire, for in that caſe it would burſt, and might do no ſmall miſchief.

RECREATION L.

The communicative buſts.

LET there be two heads of plaſter of Paris, placed on pedeſtals, on the oppoſite ſides of a room. There muſt be a tin tube of an inch diameter, that muſt paſs from the ear of one head, through the pedeſtal, under the floor, and go up to the mouth of the other. Obſerve, that the end of the tube which is next the ear of the one head, ſhould be conſiderably larger than that end which comes to the mouth of the other. Let the whole be ſo diſpoſed that there may not be the leaſt ſuſpicion of a communication.

Now, when a perſon ſpeaks, quite low, into the ear of one buſt, the ſound is reverber-

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verberated through the length of the tube, and will be distinctly heard by any one who shall place his ear to the mouth of the other. It is not necessary that the tube should come to the lips of the bust. If there be two tubes, one going to the ear, and the other to the mouth of each head, two persons may converse together, by applying their mouth and ear reciprocally to the mouth and ear of the busts; and at the same time other persons that stand in the middle of the chamber, between the heads, will not hear any part of their conversation.

RECREATION LI.

The oracular head.

PLACE a bust on a pedestal in the corner of a room, and let there be two tubes, as in the foregoing Recreation, one of which must go from the mouth and the other from the ear of the bust, through the pedestal, and the floor, to an under apartment.

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partment. There may be likewiſe wires that go from the under jaw, and the eyes of the buſt, by which they may be eaſily moved.

A perſon being placed in the under room, and at a ſignal given applying his ear to one of the tubes, will hear any queſtion that is aſked; and immediately reply, moving at the ſame time the mouth and the eyes of the buſt, by means of the wires.

RECREATION LII.

A ſolar ſonata.

IN a large caſe, ſuch as is uſed for dials and ſpring clocks, the front of which, or at leaſt the lower part of it, muſt be of glaſs, covered on the inſide with gauze, let there be placed a barrel organ, which, when wound up, is prevented from playing, by a catch that takes a toothed wheel at the end of the barrel. To one end of

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this catch there must be joined a wire, at the end of which there is a flat circle of cork, of the same dimension with the inside of a glass tube, in which it is to rise and fall. This tube must communicate with a reservoir that goes across the front part of the bottom of the case, which is to be filled with spirits, such as is used in thermometers, but not coloured, that it may be the better concealed by the gauze.

This case being placed in the sun, the spirits will be rarefied by the heat, and rising in the tube, will lift up the catch or trigger, and set the organ in play; which it will continue to do as long as it is kept in the sun; for the spirits cannot run out of the tube, that part of the catch to which the circle is fixed being prevented from rising beyond a certain point, by a check placed over it. Care must be taken to remove the machine out of the sun before the organ runs down, that its stopping may be evidently effected by the cold.

When

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When the machine is placed againſt the ſide of a room on which the ſun ſhines ſtrong, it may conſtantly remain in the ſame place, if you incloſe it in a ſecond caſe, made of thick wood, and placed at a little diſtance from the other. When you want it to perform, it will be only neceſſary to throw open the door of the outer caſe, and expoſe it to the ſun.

But if the machine be moveable, it will perform in all ſeaſons by being placed before the fire; and in the winter it will more readily ſtop when removed into the cold.

A machine of this ſort is ſaid to have been invented by Cornelius Dreble, in the laſt century. What the conſtruction of that was we know not; but might very likely be more complex, but could ſcarce anſwer the intention more readily.

RECRE-

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RECREATION LIII.

An automatous harpſichord.

UNDER the keys of a common harpſichord let there be fixed a barrel, ſomething like that in a chamber organ, with ſtops or pins correſponding to the tunes you would have it play. Theſe ſtops muſt be moveable, ſo that the tunes may be varied at pleaſure. From each of the keys let there go a wire perpendicular down; the ends of theſe wires muſt be turned up for about one-fouth of an inch. Behind theſe wires let there be an iron bar, to prevent then from going too far back. Now, as the barrel turns round, its pins take the ends of the wires, which pull down the keys, and play the harpſichord. The barrel and wires are to be all encloſed in a caſe.

In the chimney of the ſame room where the harpſichord ſtands, or at leaſt in one adja-

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adjacent, there muſt be a ſmoke jack, from whence comes down a wire, or cord, that, paſſing behind the wainſcot adjoining the chimney, goes under the floor, and up one of the legs of the harpſichord, into the caſe, and round a ſmall wheel fixed on the axis of that firſt mentioned. There ſhould be pullies at different diſtances, behind the wainſcot and under the floor, to facilitate the motion of the chord.

This machinery may be applied to any other keyed inſtrument, as well as to chimes, and to many otherpurpoſes where a regular continued motion is required.

An inſtrument of this ſort may be conſidered as a perpetual motion, according to the common acceptation of the term, for it will never ceaſe going till the fire be extinguiſhed, or ſome parts of the machinery be worn out.

RECRE-

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RECREATION LIV.

A ventoſal ſymphony.

AT the top of a ſummer-houſe, or other building, freely expoſed to the wind, let there be fixed the wings, or compounded vane AB (Pl. XVIII. Fig. 3.) on which is the pinion C, that takes the toothed wheel D, fixed on the axis E F, which at its other end carries the wheel G, that takes the pinion H. All theſe wheels and pinions are to be between the roof and the cieling of the building. The pinion H is fixed to the perpendicular axis I K, which goes down very near the wall of the room, and may be covered after the ſame manas are bell-wires. At the lower end of the axis I K there is a ſmall pinion L, that takes the wheel M, fixed on the axis of the great wheel NO. In this wheel there muſt be placed a number of ſtops, correſponding to the tunes it is to play. Theſe ſtops are to be moveable, that the tunes may be altered at pleaſure. Againſt this

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wheel there muſt hang twelve ſmall bells, anſwering to the notes of the gamut. Therefore, as the wheel turns round, the ſtops ſtriking againſt the bells, play the ſeveral tunes. There ſhould be a fly to the great wheel, to regulate its motion when the wind is ſtrong. The wheel N O, and the bells are to be encloſed in a caſe.

There may be ſeveral ſets of bells, one of which may anſwer to the tenor, another to the treble, and a third to the baſe; or they may play different tunes, according to the ſize of the wheel. As the bells are ſmall, if they are of ſilver, their tone will be the more pleaſing.

Inſtead of bells, glaſſes may be here uſed, ſo diſpoſed as to move freely at the ſtroke of the ſtops. This machinery may likewiſe be applied to a barrel-organ; and to many other uſes.

RECRE-

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RECREATION LV.

The nocturnal reveilleur.

AGAINST the wall of a room, near the cieling, fix a wheel of 12 or 18 inches diameter; on the rim of which place a number of bells in tune, and, if you pleaſe, of different ſizes. To the axis of this wheel there ſhould be fixed a fly, to regulate its motion; and round the circumference there muſt be wound a rope, to the end of which is hung a weight.

Near to the wheel let a ſtand be fixed, on which is an upright piece that holds a balance or moveable lever, on one end of which reſts the weight juſt mentioned, and to the other end muſt hang an inverted hollow cone, or funnel, the aperture of which is very ſmall. This cone muſt be graduated on the inſide, that the ſand put

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in may anſwer to the number of hours it is to run. Againſt the upright piece, on the ſide next the cone, there muſt be fixed a check, to prevent it from deſcending. This ſtand, together with the wheel, may be encloſed in a caſe, and ſo contrived as to be moved from one room to another with very little trouble.

It is evident from the conſtruction of this machine, that when a certain quantity of the ſand is run out, the weight will deſcend, and put the wheel in motion, which motion will continue till the weight comes to the ground. If the wheel be required to continue longer in motion, two or more pullies may be added, over which the rope may run.

The ſize of the bells ſhould be adapted to the ſomniferous diſpoſition of the party they are intended to rouze; or, if you pleaſe, a drum or tabor may be added, the

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the ſtick to which may be fixed in the ſide of the room, by a ſwivel that goes through the middle of it; and one end of it being lifted up by teeth placed on the circumference of the wheel, the other end will alternately ſtrike the drum.

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RECREATION LVI.

A muſical caſcade.

WHERE there is a natural caſcade, near the lower ſtream, but not in it, let there be placed a large wheel, equal to the breadth of the caſcade: the diameter of this wheel, for about a foot from each end, muſt be much leſs than that of the middle part; and all the water from the caſcade muſt be made to fall on the ends*. The remaining part of the wheel which is to be kept free from the water, muſt conſiſt of bars, on which are placed ſtops, that ſtrike againſt bells, as in the 54th Recreation: theſe ſtops muſt likewiſe be moveable, but larger than in that Recreation, as well as the bells, that they may be heard much farther. It is evident

* The water that falls on the wheel may paſs thro' pipes, ſo that part of it may be made occaſionally to paſs over or fall ſhort of the wheel, as you would have the time of the muſic quicker or ſlower.

from

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from the conſtruction of this machine, that the water falling on the floats at the ends of the wheel, will make the ſtops, which are adapted to different tunes, ſtrike the notes of thoſe tunes on the reſpective bells. Two or three ſets of bells may here be placed on the ſame line, when the caſcade is ſufficiently wide.

Where there is not a natural caſcade, one may be artificially conſtructed, by raiſing part of the ground, wherever there is a deſcent of water; whether it be a ſtream that ſupplies a reſervoir or fountain, or ſerves domeſtic uſes; or if it be refuſe water that has already ſerved ſome other purpoſe.

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RECREATION LVII.

Reverberated ſounds.

SOUND, like light, after it has been reflected from ſeveral places, may be collected in one point, as into a focus; and it will be there more audible than in any other part, even than at the place from whence it proceeded. On this principle it is that a whiſpering gallery is conſtructed.

The form of this gallery muſt be that a concave hemiſphere*, as ABC (Pl. XVIII. Fig. 4.) and if a low ſound or whiſper be uttered at A, the vibrations expanding themſelves every way will impinge on the points D D D, &c. and from thence be reflected to E E E, and from thence to the points F and G, till at laſt they all meet

* A cylindric or elliptic arch will anſwer ſtill better than one that is circular.

in

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in C, where, as we have ſaid, the ſound will be the moſt diſtinctly heard.

Upon this principle alſo it is that the ſpeaking trumpet is formed. For the ſound, in paſſing through the long and narrow part of the tube, is continually reflected from its curved ſide into the axis, and by that mean is prevented from ſpreading till at its exit from the tube, whereby the ſtrength of the ſound is greatly increaſed.

As by the laſt aphoriſm, page 200, the angle of reflected ſound is equal to that of its incidence, if we know the point from which any ſound proceeds, and the place from which it is reflected, we may eaſily find the point in which its echo will be heard.

To hear the echo of one ſyllable, we muſt be at the diſtance of 120 feet from the reflecting ſurface: for two ſyllables, 240 feet; for three ſyllables 360 feet, &c.

For

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For when we ſpeak diſtinctly we ſcarce pronounce more than three or three ſyllables and a half in a ſecond; and as by aphoriſm 13, ſound goes 1142 feet in a ſecond, if the diſtance between the ſpeaker and the reflecting ſurface were leſs than 360 feet, the firſt ſyllable would be returned before the laſt was pronounced*, and therefore the echo could not be diſtinctly heard. The echo in Woodſtock Park is ſaid to return 17 ſyllables in the day, and 20 in the night; for then the air being colder and denſer, by aphoriſm 15, the ſtrength of the ſound muſt be greater. From hence we may determine nearly, the diſtance of an object that is inacceſ-

* According to the aphoriſm, the diſtance ſhould be 380 feet; for the firſt ſyllable muſt go as far as is equal to the time the two laſt ſyllables are pronouncing, that is, two-thirds of a ſecond; therefore the diſtance ſhould be equal to two-thirds of 1142 feet, or $760\frac{2}{3}$, that is, $380\frac{1}{3}$ going and coming. But as ſome time muſt be allowed for the reflecting ſurface to be made to vibrate by the impinging ſound, the firſt diſtance, 360 feet, will be very near the truth.

ſible;

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ſible; for if an echo of 10 ſyllables be reflected from the ſide of a church or tower, it follows, from what has been ſaid, that the object muſt be 1200 feet diſtant.

The ſame ſound may have ſeveral echoes, if there be ſeveral reflecting ſurfaces ſo diſpoſed as to make it reverberate to the ſame point. Thus a violin, or other inſtrument, when ſounded in a room where there are ſeveral arches of the ſame form, will ſound like a number of violins of the ſame ſize playing in concert: or if the arches be of different forms, there will ſeem to be different inſtruments playing the ſame tune.

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RECREATION LVIII.

The converſive ſtatue.

PLACE a concave mirror of about two feet diameter, as A B* (Plate XVIII. Fig. 5.) in a perpendicular direction. The focus of this mirror may be at 15 or 18 inches diſtance from its ſurface. At the diſtance of about five or ſix feet let there be a partition, in which there is an opening E F, equal to the ſize of the mirror; againſt this opening muſt be placed a picture, painted in water-colours, on a thin cloth, that the ſound may eaſily paſs through it †.

* Both the mirrors here uſed may be of tin or gilt paſteboard, this experiment not requiring ſuch as are very accurate.

† A Recreation of this kind may be performed in a field or garden, between two hedges, in one of which the mirror AB may be placed, and in the other an opening artfully contrived. The more effectually to conceal the cauſe of this illuſion,

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Behind the partition, at the diſtance of two or three feet, place another mirror GH, of the ſame ſize as the former, and let it be diametrically oppoſite to it.

At the point C let there be placed the figure of a man ſeated on a pedeſtal, and let his ear be placed exactly in the focus of the firſt mirror; his lower jaw muſt be made to open by a wire, and ſhut by a ſpring; and there may be another wire to move the eyes; theſe wires muſt paſs through the figure, go under the floor, and come up behind the partition.

Let a perſon, properly inſtructed, be placed behind the partition near the mirror. You then propoſe to any one to ſpeak ſoftly to the ſtatue, by putting his

illuſion, the mirror AB may be fixed in the wainſcot, and a gauze, or any other thin covering, thrown over it, as that will not in the leaſt prevent the ſound from being reflected.

mouth

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mouth to the ear of it, aſſuring him that it will anſwer inſtantly. You then give the ſignal to the perſon behind the partition, who, by placing his ear to the focus I, of the mirror G H, will hear diſtinctly what the other ſaid, and moving the jaw and eyes of the ſtatue, by the wires, will return an anſwer directly, which will, in like manner be diſtinctly heard by the firſt ſpeaker.

Remark. This Recreation appears to be taken from the Century of Inventions of the Marquis of Worceſter; one of thoſe men of ſublime genius, who are able to perform actions infinitely ſuperior to the capacity, or even the comprehenſion, of the mere ſcholar or man of buſineſs; and though his deſigns, at the time they were publiſhed, were treated with ridicule and neglect, by the great and little vulgar, who, judging by their own abilities, are ever ready to condemn what they cannot com-

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Fig. 1. p 196.

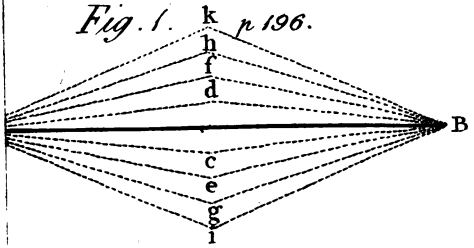
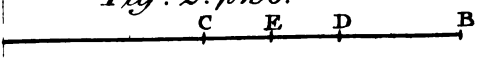


Fig. 2. p 198.



p 209

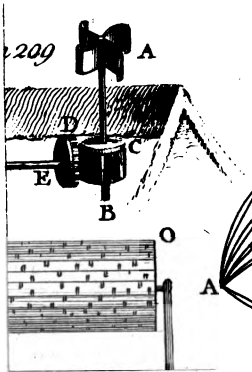


Fig. 4. p 216.

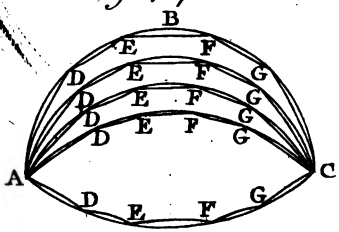
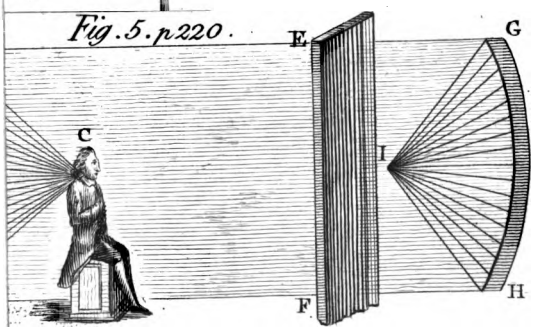


Fig. 5. p 220.



T. Hodge Sculp.

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comprehend, yet they are now known to be generally, if not univerſally, practicable. The words of the Marquis are theſe: "How to make a brazen or ſtone head, in the midſt of a great field or garden, ſo artificial and natural, that, though a man ſpeak never ſo ſoftly, and even whiſper into the ear thereof, it will preſently open its mouth, and reſolve the queſtion in French, Latin, Welch, Iriſh, or Engliſh, in good terms, uttering it out of its mouth, and then ſhut it until the next queſtion be aſked."

RECREATION LIX.

The Organ.

THE recreation this inſtrument affords is known to every one; but what we here propoſe is a deſcription of the ſeveral parts of this moſt noble and comprehenſive of all muſical machines, and of the manner by which its numerous ſounds

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are produced: and ſuch a deſcription will, perhaps, afford a perſon of an ingenious diſpoſition a recreation little inferior to the ſounds themſelves.

There are various ſorts of organs, but that we ſhall here deſcribe is the grand or church organ, which conſiſts of two parts, the main body, called the great organ, and the poſitive or little organ, which forms a ſmall caſe or buffet, commonly placed before the great organ. The ſize of an organ is generally expreſſed by the length of its largeſt pipe: thus they ſay, an organ of 8, 16, 32 feet, &c.*

The ſeveral parts of the church organ are as follows: HIH (Plate XIX. Fig. 1.) is the ſound-board, which is compoſed of two parts, the upper board or cover HHH,

* The organ in the cathedral church at Ulm, in Germany, is 93 feet high, and 28 broad: its largeſt pipe is 13 inches diameter, and it has 16 pair of bellows.

and

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and the under board H I, which is much thicker than the other; each of these consists of several planks, laid with their edges to each other, and joined very close together. In the under side of the lower board there are made several channels, which run in the direction L L, M M, &c. and are continued as far as there are stops in the organ, and come almost to the edge H K. These channels are covered over, very close, with parchment or leather, all the way, except a hole that is commonly at the fore end next H K, upon which a valve or puff is placed. These channels are called partitions. When this valve or flap is shut it keeps out the air, and admits it when open. On the upper side of the lower board there are likewise cut several broad, square channels, lying cross the former, but not so deep as to reach them; these lie in the direction L N, P Q, &c. To fit these channels there are the same number of

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wooden ſliders or regiſters *f*, *f*, *f*, &c. running the whole length; and theſe may be drawn out, or thruſt in, at pleaſure. The number of theſe is the ſame as that of the ſtops in the organ.

K K K is the wind-cheſt, which is a ſquare box, fitted cloſe to the under ſide of the lower board, and made air tight, ſo that no air can get out, but what goes through the valves, along the partitions.

V V are the valves or puffs, which open into the wind-cheſt; they are all incloſed in it, and may be placed in any part of it, as occaſion ſhall require. One of theſe valves, with the ſpring that ſhuts it, and the wire that opens it, is repreſented by Fig. 2.

C, D, E, F, &c. are the keys on which the fingers are placed, when the organ is played: theſe keys lie over the horizontal bar

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bar of wood W, in which are ſtuck an equal number of wire pins *z*, *z*, on which keys are fixed; and the keys move up and down on the bar, as on a center. There is another bar, againſt which the keys fall when put down, and which is here marked 3: on this alſo are ſeveral wires, which go through the keys, to guide them; and on this bar a liſt is faſtened to hinder the keys from knocking againſt the wood.

The keys are made to communicate with the valves ſeveral ways as we ſhall now deſcribe. Firſt, *s*, *s*, *s*, are the key-rollers, moving on the pivots *t*, *t*: theſe rollers lie horizontally, one above another, and are of ſuch a length as to reach from the valve to the key: *a*, *a*, *a*, are arms or levers fixed to the key-rollers: *w*, *w*, the valve wires fixed to the arms *a*, *a*, and to the valves V, and go through the holes *b*, *b*, in the bottom of the wind-cheſt: *b*, *b*, *b*,

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are likewiſe arms fixed to the key-rollers: *d*, *d*, *d*, the key-wires, fixed to the arms, *b*, *b*, and to the keys C, D, E. Now when the end of any one of the keys C, D, E, is put down, it pulls down the arm *b*, by the wire *d*, which turns about the roller *s* with the arm *a*, that pulls down the wire *w*, which opens the valve, that is ſhut by the ſpring as ſoon as the preſſure is taken off the key. In this conſtruction there muſt be a worm-ſpring faſtened to the key, and to the bar W, on the farther ſide, to keep down the end 5, of the key.

Another method of opening the valves is thus: *x y*, *x y*, are ſlender levers, moveable on the centers 1, 1: 5*x*, 5*x*, are wires going from the farther ends of the keys to the ends *x* of the levers: *y* V, *y* V, are other wires, reaching from the ends *y* of the levers, through the holes *h*, to the valves V. So that putting down the key C, D, &c. raiſes the end 5, which thruſts

up

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up the end *x* of the lever, by the wire 5 *x*; this depreſſes the end *y* of the lever, which pulls down the wire *y* V, and opens the valve V.

A third way of opening the valves is this: at the end of the key 6, is a lever 8, 9, moving in the center 7. This makes, with the key, a compound lever. From the end 9, a wire goes to the valve. Now the putting down the end 6 of the key, raiſes the end 8, which depreſſes the end 9, of the lever 8, 9, pulls down the wire, and opens the valve. There is only one of theſe drawn in the ſcheme, and but a few of the others; to avoid confuſion.

R, R, are the rollers, to move the ſliders, by help of the arms *c f*, *c f*, which are fixed horizontally in theſe rollers; *k e*, *k e*, are alſo levers fixed in the rollers; *l e*, *l e*, are the handles, which lie horizontally, and paſs through the holes *l*, *l*; they are

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faſtened to the lever *k e*, being moveable about a joint at *e*.

Now, any handle *l p*, being drawn out, pulls the end *e* toward *l*, which turns about R *k*, along with the arm *c f*; and the end *f* pulls out the ſlider *f g*; and when *p* is thruſt in, the arm *c f* likewiſe thruſts in the ſlider *f g*.

Upon the ſeveral rows of holes which appear on the top of the upper board, there are ſet up an equal number of rows of pipes. The pipes of an organ are of two kinds, the one has a mouth like a flute, the other with reeds. The firſt, called pipes of mutation, conſiſt (1.) of a foot AA, BB (Fig. 3.) which is a hollow cone, that receives the wind that is to ſound the pipe: (2.) to this foot is faſtened the body of the pipe B B D D. Between the foot and the body of the pipe is a diaphragm or partition F E F, that has a long

but

but narrow aperture, by which the wind comes out: over this aperture is the mouth BBC, whoſe upper lip C, being level, cuts the wind as it comes out.

The pipes are of pewter, of lead mixed with a twelfth part of tin, and of wood. Thoſe of pewter are always open at their extremities: their diameter is very ſmall, and their ſound very clear and ſhrill. Thoſe of lead mixed with tin are larger: the ſhorteſt are open, the longeſt quite ſtopped: thoſe of a mean ſize are partly ſtopped, and have beſide a little ear on each ſide the mouth, to be drawn cloſer or ſet farther aſunder, in order to raiſe or lower the ſound. The wooden pipes are ſquare and their extremity is ſtopped with a valve or tampion of leather. The ſound of the wooden and leaden pipes is very ſoft: the large ones ſtopped are commonly of wood, the ſmall ones of lead. The longeſt pipes give the graveſt ſound, and the ſhorteſt the moſt acute; their lengths and widths

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are determined by a fixed proportion to their ſounds, and their diviſions are regulated by a rule, which is called the diapaſon. The longeſt has commonly ſixteen feet; but in very large organs it has thirty-two feet. The pedal tubes are always open, though made of wood and of lead. Whatever note any open pipe ſounds, when its mouth is ſtopped, it will ſound an octave lower; and a pipe of twice its capacity will likewiſe ſound an octave lower.

A reed-pipe conſiſts of a foot AABB, (Fig. 4.) that carries the wind into the ſhalot or reed CD, which is a hollow demi-cylinder, fitted, at its extremity D, into a ſort of mould, by a wooden tampion G. The ſhallot is covered with a plate of copper KKLL, fitted, at its extremity I I, into the mould, by the ſame wooden tampion. Its other extremity K K, is at liberty, ſo that the air entering the ſhallot makes it tremble, or ſhake againſt the reed; and the longer that part of the tongue

tongue I L, which is at liberty, is made, the deeper is the ſound. The mould I I, that ſerves to fix the ſhallot or reed, the tongue, tampion, &c. ſerves alſo to ſtop the foot of the pipe, and make the wind go out wholly at the reed. Laſtly, in the mould is ſoldered the tube H H, whoſe inward opening is a continuation of that of the reed: the form of this tube is different in different ranks of pipes. The degree of acuteneſs or gravity in the ſound of a reed-pipe, depends on the length of the tongue, and that of the pipe C K, taken from the extremity of the ſhallot, to the extremity of the tube. The quantity or intenſion of the ſound depends on the width of the reed, the tongue, and the tube; as alſo on the thickneſs of the tongue, the figure of the tube, and the quantity of wind. To diverſify the ſounds of the pipes, a valve is added to the port-vent, which makes the wind go out in fits or ſhakes. In Fig. 1. X repreſents a flute-pipe of wood, Z a flute-pipe of metal, Y a trum-

pet-

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pet-pipe of metal. The pipes, to prevent them from falling, pass thro' holes made in boards, placed upon the upper board.

The pipes are made to communicate with the wind-chest in the following manner. There are holes bored that go thro' the upper and lower boards, and through the slider, (when it is drawn out) into the partition below; so that any pipes placed upon those holes will then communicate with the partition, which, by its valve, communicates with the wind-chest. But when the slider is thrust in its holes do not answer to those in the upper and lower boards, therefore the communication is stopped, so that no wind can get to the pipe,

To every large organ there must be at least two pair of bellows, which are marked in Fig. 1. by 9T, 9T. O, O, are the handles, moving upon the axes *n n*, *n n*. Each of these

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theſe bellows conſiſts of two boards, the loweſt of which is immoveable; and in this there is a valve *r*, opening inwards and a tube leading to it, called the conveying tube. There is alſo a hole in this under board, from which a tube leads to the port-vent, which is a ſquare tube marked 4, riſing upward, and inſerted into the under ſide of the wind-cheſt at 2. In the tube leading to the port-vent there is a valve that opens toward the port-vent, and ſuffers the air to go up the port-vent, but not to return. Now the handle O being put down, raiſes the upper board T, and the air enters through the valve *r*, and when the handle is let go, the weight of the upper board, which carries three or four pound to every ſquare foot, continually deſcending, drives the air through the port-vent to the ſound-board: and as the bellows work alternately one pair is conſtantly deſcending, which occaſions a continual blaſt through the port-vent. In chamber-organs there is but one pair of bellows,

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bellows, but they are formed of three boards, in the manner of a ſmith's bellows, and ſo have a continual blaſt. All the internal ſtructure of the organ is concealed from the ſight by the front of the inſtrument, which ſtands upon the part between the numbers 3 and 6 (Fig. 1.).

In every organ the number of partitions LL, MM, &c. there are in the ſound-board (Fig. 1.) that of the valves V, V; that of the rollers *s*, *s*; or of the levers *x*, *y*, or 8, 9, and their wires: and that of the keys A B C, &c. muſt be always equal. Large organs have commonly four or five ſets of keys, beſide thoſe that belong to the pedals or large pipes, the ſtops to which are played by the feet. The keys of an organ are uſually divided into four octaves, which are, the ſecond ſub-octave, firſt ſub-octave, middle octave, and firſt octave. Each octave is divided into twelve ſtops or frets, of which ſeven are black and five white; the former mark the natural

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tural notes, and the latter the artificial notes, that is, flats and ſharps. The number of keys, therefore, when there are four octaves, muſt be 48. Some organiſts add one or more ſtops to the firſt and ſecond ſub-octaves. The pedals have two or three octaves, at the option of the organiſt; ſo that the number of ſtops is indeterminate. The keys are placed between C C (Fig. 1.) but the ſcheme could not contain them all. There are alſo as many handles *l*, *l*, &c. rollers R, R, &c. ſliders *f*, *f*, &c. as there are ſtops upon the organ; and it muſt be obſerved, that between the ſliders, *f*, *f*, &c. there are as many ſliders on the right hand, and the ſame number of handles and rollers, and other rows of pipes placed between L N, P Q, &c. which could not be expreſſed in the figure.

The leaſt pipes and partitions are placed toward the middle of the organ, and the greateſt on the outſide. The ſtops

of

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of an organ have various denominations, according to the ſounds they are to produce; ſome of which are diapaſon, principal, fifteen, twelfth, tearce, cornet, trumpet, French horn, vox humana, flute, baſſoon, Cremona, &c. There is a contrivance to ſwell the notes of ſome of the ſtops, by placing the treble or ſmall pipes in a kind of a cheſt, which is perfectly cloſed or opened with the foot by means of a pedal. When the pipes are cloſe ſhut up, the ſound is ſcarce audible and ſeems to be at a great diſtance; but as the cheſt is wholly or in part opened or cloſed, in a gradual and uniform manner, the ſound of the pipes is increaſed or diminiſhed in the ſame proportion. In large organs, the upper or half-row of keys belong to theſe pipes; and when this part is managed by a good performer, it yields the moſt delightful muſic imaginable.

When this magnificent inſtrument is played, the handle O of the bellows is firſt put down, which raiſes the upper board T, and gives room for the air to enter by

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the valve *r*. Then the other handle O is put down; in the mean time the board T, belonging to the firſt handle, deſcending, and ſhutting the valve *r*, drives the air, through the other valve, up the port-vent, and into the wind-cheſt. Then drawing out any handle, as that of the flute-ſtop *p l*, which draws out the ſlider *f g*, all the pipes in the ſet L N are ready to play, as ſoon as as the keys C, D, E, &c. are put down therefore, if the key D be put down, it opens the correſponding valve *m* V, thro' which the air enters into the pipe X, and makes is ſound. In the ſame manner any other pipe, in the ſet LN, will ſound when its key is put down; but no pipe, in any other ſet, will ſound, till the ſlider be drawn out by its correſponding handle.

The organ is not only the moſt grand but the moſt ancient of all compound muſical machines. Vitruvius deſcribles an hydraulic organ in the tenth book of his architecture, which was celebrated by the emperor

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emperor Julian, in an epigram. St. Jerome mentions an organ that had twelve pair of bellows, and whose sound might be heard at the distance of a mile.

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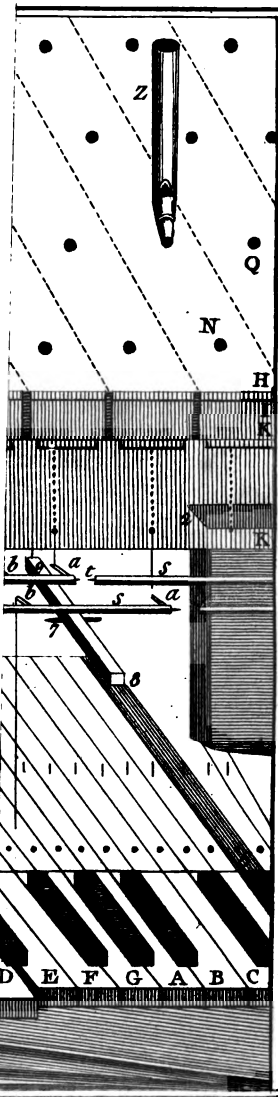


Fig. 2. p. 226.

Fig. 3. p. 230.

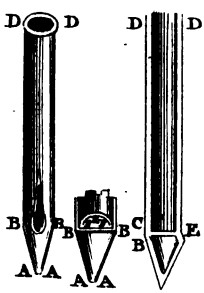
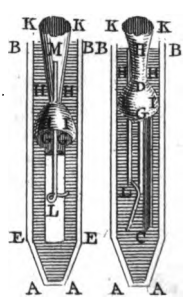


Fig. 4. p. 232.



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THE

CONTENTS.

OPTICS.

GENERAL DEFINITIONS Page 1
GENERAL APHORISMS 3

DIOPTRICS.

DEFINITIONS 5
APHORISMS 7

Properties of refracted light, aph. 1 to 3
—Properties of lenſes, aph. 4 to 6.
Theory of refracting teleſcopes 8
——— of reflecting teleſcopes 11
——— of microſcopes 12

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RECREATION I. p. 14

Optical illuſion.

Three pieces of money being placed in a veſſel (Pl. III. Fig. 1.) out of the view of a ſpectator, and water being poured into the veſſel all thoſe pieces become viſible—by the refraction of the light thro' the water.

RECREATION II. p. 15

Optical augmentation.

A ſhilling being put in a glaſs of water, and a plate placed upon it, the glaſs is turned over with the plate, and there appears a half crown on the plate and a ſhilling over it—by the ſeeing the ſhilling through the top and the ſide of the water at the ſame time, and the different refraction of the light.

RECRE-

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RECREATION III. p. 17

Optical ſubtraction.

Three ſmall pieces of paper being placed againſt a wall, (Plate III. Fig. 2.) a perſon by ſhutting one of his eyes can ſee only two of them—the rays that come from one of the pieces falling always on the optic nerve, and not on the retina.

RECREATION IV. p. 18

Alternate illuſion.

A ſilver ſeal when viewed through a convex lens, appears alternately engraved and in relief—conjecture on the cauſe of this remarkable phenomenon p. 90 (note)

RECREATION V. p. 20

The camera obſcura.

A convex lens is placed in the window-ſhutter of a dark room, and a concave

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pasteboard, lined with white paper, is placed in the focus of the lens, whereby the objects without the room are painted on the paper, but inverted—method of making them appear erect, page 22 (note)—this apparatus improved by a mirror placed in different positions, p. 22—presents the most pleasing and natural of all pictures 25

RECREATION VI. p. 25

To shew the spots on the sun's disk, by its image in the camera obscura.

By placing a scioptric ball, that is, a ball of wood in which a lens is fixed, opposite the sun, which will throw its image on the paper—this image to be viewed through another lens, p. 26

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RECREATION VII. p. 27

To magnify ſmall objects by means of the ſun's rays let into a dark chamber.

By throwing the rays on a concave mirror, and holding the ſmall objects, ſtuck on ſlips of glaſs, near the focus of the mirror, by which mean their images are reflected on the wall.

RECREATION VIII. p. 28

The portable camera obſcura.

A plate of glaſs is placed in a horizontal frame of wood that is ſupported by four legs, which fold up (Plate III. Fig. 3.) Under the frame is a box, that likewiſe folds up, and at the bottom of it are a tube and a mirror, by which the objects are reflected to the glaſs—advantage of this camera over others, p. 30—manner of drawing objects by this machine p. 31

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RECREATION IX. p. 32

The magic lantern.

The origin of this machine—it consists of a tin box, at one end of which is a concave mirror; in the other end is fixed a lens, and between them is placed a lamp; before the lens is fixed a square tin tube in which there is a groove, and through this groove the glasses that contain the objects are passed: in this tube is placed another, that is moveable, and contains two lenses, which throw the objects on a cloth—method of painting the glasses, p. 37—proposal of improving this machine by using moveable objects p. 39

RECREATION X. p. 40

To represent a tempest by the magic lantern.

By passing two glasses, on one of which is painted the sea and sky, and and on the other

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other ſhips, (Plate IV. Fig. 1 and 2.) through the groove at the ſame time, and giving them a proper motion—by the ſame method a battle, and many other ſubjects may be exhibited p. 42

RECREATION XI. p. 43

The nebulous magic lantern.

At the bottom of a ſquare box, whoſe height is equal to ſix times its width, (Plate IV. Fig. 3.) is placed a chafing-diſh of hot coals, on which incenſe is burnt, and on the ſmoke that comes out of the top of the box is thrown the figures of the magic lantern.

RECREATION XII. p. 44

To produce the appearance of a phantom, on a box or pedeſtal placed on a table.

A common magic lantern is placed in a box, (Plate IV. Fig. 4.) in which there is an inclined mirror, that reflects the

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light of the lantern on the thick ſmoke of a chafingdiſh of coals placed on the box, and ſhows the image reflected by the glaſs—this Recreation muſt be performed in a dark room, . p. 47

RECREATION XIII. p. 48

The magical theatre.

A magic lantern muſt be provided that has a tube in two of its oppoſite ſides, (Pl. IV, Fig. 5.) in one of which tubes there muſt be ſeveral grooves, by which the ſubjects to be repreſented may be paſſed either horizontally, aſcending, or deſcending, and two or more of them at the ſame time. In the partition between the room where the lantern is, and that where the exhibition is to be ſeen, there muſt be placed a glaſs, covered with thin paper, on which the objects are to be thrown—example of a repreſentation of the ſiege of Troy, in five acts, p. 52—it is quite neceſſary that the glaſſes

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glaſſes for theſe exhibitions be accurately painted, p. 60.

CATOPTRICS.

DEFINITIONS 62
APHORISMS 63

Properties of plain mirrors, p. 63—of ſpherical convex mirrors, p. 64—of ſpherical concave mirrors, p. 65.

RECREATION XIV. p. 67

The boundleſs gallery.

Againſt each of the two ſmalleſt ends of an oblong box (Plate VI. Fig. 1.) is placed a plain mirror, and from one of them the quickſilver is taken off for the ſpace of an inch and a half, oppoſite which a hole is made in the box: the top of the box is covered with glaſs, and between the mirrors are placed ſcenes properly painted, which when viewed from the hole at the end of the box,

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box, appear as an endleſs viſta or gallery.

RECREATION XV. p. 69

The four magical mirrors.

The inſide of a ſquare box (Pl. VI. Fig. 4.) is lined with four mirrors: the top is covered with five planes of glaſs in form of the lower part of a pyramid, and on the bottom of the box are placed certain objects in relief, which when ſeen from the top are ſo reflected by the mirrors as to form an unlimited ſpace completely covered with objects.

RECREATION XVI. p. 72

The enchanted palace.

From the center of a hexagon to its circumference are drawn ſix lines, at equal diſtances, (Plate VII. Fig. 1.) and on each of them are fixed two mirrors, which are ſupported by pillars placed

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at the circumference: the top is covered with a dome, and between the ſix ſpaces objects are placed, which are reflected ſix times, and produce a very pleaſing appearance.

RECREATION XVII. p. 75

To draw an irregular figure, which ſhall appear regular when viewed in a plane mirror.

The figure is to be firſt drawn on a ſquare that contains a number of equal diviſions, (Plate VII. Fig. 2.) and then the ſeveral parts transferred to the ſame number of diviſions in a trapezium; and that diſtorted figure, when ſeen in the mirror from a determinate point of view, will appear in its natural form.

RECREATON XVIII. p. 78

The magical dial.

A dial-plate, that has a magnetic needle for a hand, is placed at the bottom of

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of a dial caſe, and toward the top of the caſe is fixed a mirror, by which the figures of the hours are reflected to the part where the dial is commonly ſeen. Another dial plate, at the back of which is concealed an artificial magnet, that is moved by the hand of that dial, is given to a perſon, who ſetting the hand privately to any hour, puts it in a drawer at the bottom of the dial-caſe, under the firſt mentioned dial, and looking in at top he ſees the reflection of the dial there, anſwer to the hour at which he ſet the other dial; the hand of the firſt being moved, by the attraction of the magnet in the other, to the ſame hour.

RECREATION XIX. p. 81.

The box of divination.

A box that contains four caſes, on each of which a number is wrote, and at the bottom of which a magnet is concealed,

(Plate

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(Plate VIII. Fig. 1.) is placed on a table: under that part of the table are placed four moveable circles, that have each a needle, and under them is a drawer, that contains a mirror, ſo that by looking into the drawer you ſee, by that mirror, in what order are placed the boxes that have the numbers.

RECREATION XX. p. 84

The magical perſpectives.

A ſmall common perſpective (Plate VIII. Fig. 6.) is fixed on a hollow ſtand of wood; in this perſpective is placed a mirror, which is moved by the inner tube, ſo as to ſhow any object under the hollow ſtand. Three of theſe perſpectives are ſet over three holes in the top of a box, (Fig. 5.) at the bottom of which is placed a moveable circle, that is divided into twenty-one equal parts, and contains a magnetic needle: this box is ſet on a table, under which

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is concealed a magnetic bar, that being privately placed in any poſition. determines that of the circle in the box, and conſequently brings any of the objects painted on it under the ſeveral perſpectives.

RECREATION XXI. p. 93

The penetrative perſpective.

In a box or caſe that has two prominent parts or arms, (Plate X. Fig. 1.) are placed four mirrors, and in each of the arms is fixed the tube of a perſpective glaſs, ſo that the object next the end of one perſpective, being reflected by the four mirrors, is ſeen at the end of the other, and appears as if viewed through the two perſpectives, and conſequently is perfectly viſible when an opaque body is placed between thoſe two perſpectives.

RECRE-

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RECREATION XXII. p. 96

The magician's mirrors.

Two glaſſes are fixed in the partition of a room, at about a foot diſtant from each other; behind theſe glaſſes are placed two mirrors, inclined in a proper angle, ſo that a perſon looking into one of them, inſtead of ſeeing his own face ſees that of another perſon who at the ſame time looks into the other glaſs. Method of improving this Recreation, by putting the two glaſſes in adjoining rooms, p. 97—properties of plain mirrors when placed in different poſitions, p. 98

RECREATION XXIII. p. 100

Polemoſcopes.

Theſe inſtruments conſiſt of a tube that contains an inclined mirror, and has an eye-

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eye-glaſs of a proper focus, ſo that while the tube is pointed at one object you ſee another. By placing an inſtrument of this ſort at the top of a wall, while you ſtand at the bottom, you ſee what paſſes on the other ſide. p. 101

RECREATION XXIV. p. 102

The enchanted mirrors.

In four parallel ſides of a cubical box are fixed four glaſſes, repreſenting mirrors, and within the box are placed two mirrors, that croſs it diagonally. When four perſons look into the glaſſes, each of them ſees, inſtead of his own face, that of the perſon next him, and who appears at the ſame time to be placed directly oppoſite to him.

RECRE-

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RECREATION XXV. p. 103

The animated optic balls.

This pleaſing piece of optics conſiſts of an oblong box, (Pl. IX. Fig. 2.) three fourths of the upper part of which is divided from the lower by a horizontal partition, and is decorated with paintings. In the lower part of the remaining fourth is placed an inclined plane, in the middle of which is a ſerpentine groove, and in the other parts are paintings or objects in relief: in the upper part of this ſpace is a mirror, placed in a proper angle to reflect the objects on the plane. At the end of the box is a ſmall opening, by which ivory balls, that may be painted with different colours, are put in, and running down the groove in the inclined plane, paſs out at the bottom, and are raiſed to the ſame opening again by a machine placed

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there for that purpoſe. Part of the top of this box is covered with glaſs, lined with gauze, and near the inclined plane is placed a lamp. In the end of the box oppoſite the plane, there is an opening in which a glaſs is fixed, and thro' which the objects on the inclined plane are ſeen, reflected by the mirror, and being all inverted, the balls ſeem to roll up the mirror, and paſs out at the top of the box.

RECREATION XXVI. p. 111

The optic balls by a double reflection.

This box differs from the laſt in having a mirror where the inclined plane is there placed, and in the planes being placed at the oppoſite end of the box. There may alſo be an additional number of grooves, with a ſmall inclination, thro' which the balls may paſs: and if there be ſufficient room, there may be two ſets of grooves, by which the balls will ſeem in the mirror to rencounter and paſs over each other.

RECRE-

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RECREATION XXVII. p. 114.

To deſcribe on a plane ſurface an irregular figure, which ſhall appear regular when placed oppoſite a multiplying glaſs, and ſeen by reflection through an aperture made in the center of the drawing.

The plan of the multiplying glaſs (Plate X. Fig. 4.) being drawn on paper, the deſign is to be drawn on that. The glaſs is to be fixed on a ſtand at one end of a box, and at the other end is to be a frame that holds a paper, in the middle of which is a hole, and on which is to be tranferred the deſign drawn on the multiplying glaſs, and which will then be quite diſtorted; but being ſeen in the mirror, by looking through the hole, it will appear quite regular.

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RECREATION XXVIII. p. 120

To describe on a plane surface a deformed figure, which shall appear regular when viewed by reflection in a cylindrical mirror.

Part of the surface of the cylinder (Pl. XI. Fig. 1.) is to be divided by lines, into twelve parts, in proportion to those of the diameter of the circle C D, Fig. 2. The parallelogram, Fig. 3. is likewise to be divided into twelve equal parts, and on them a regular figure is to be drawn, and then transferred to the same number of parts, which will be reflected on the plane D G, by the lines on the cylinder, and the figure will then appear deformed, but being seen from the point of view E, will be quite regular. A similar experiment may be made with prismatic and other mirrors, p. 124

RECRE-

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RECREATION XXIX. p. 123

Optical appearances.

A bottle half full of water being placed near the focus of a concave mirror, appears not only inverted, but the water at the top of the bottle and the bottom of the bottle empty. If the bottle be inverted and placed before the mirror, its image will appear erect, and the water at the bottom of the bottle. If while the bottle is inverted it be uncorked, it will appear, that while the upper part is emptying the bottom part is filling.

RECREATION XXX. p. 128

The perspective mirror.

At one end of an oblong box (Plate XII. Fig. 1.) is placed a concave mirror; near the upper part of the opposite end a hole is made, and about the middle of the box is placed a hollow frame of

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pasteboard, that confines the view of the mirror. The top of the box next that end in which the hole is made is covered with a glass; and under the hole are placed, in succession, different pictures, properly painted, which are thrown into perspective by the mirror, and produce an appearance that is highly pleasing.

RECREATION XXXI. p. 130

To set fire to a combustible body, by the reflection of two concave mirrors.

These two mirrors (Plate XII. Fig. 2.) are placed at a considerable distance, and in the focus of one of them is put a live coal, in that of the other some gunpowder and by the blowing on the coal, the gunpowder will take fire, though the distance between the mirrors be several feet.

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RECREATION XXXII. p. 132

The real apparation.

A hole is made in a partition, (Plate XII. Fig. 3.) and behind it is placed a large concave mirror, and a ſtrong light, that muſt not be viſible at the hole. On the ſame ſide of the partition, and directly under the hole, is fixed, in an inverted poſition, the object that is to appear without the partition. A perſon being placed in a proper point of view will ſee the object on the outſide, and in an erect poſition—The figure of an abſent or deceaſed friend may be made to appear by this method, p. 134—The imaginary combat by a concave mirror, p. 136

CHROMATICS.

DEFINITIONS p. 137
APHORISMS 138

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RECREATION XXXIII. p. 149

Out of a ſingle colourleſs ray of light to produce ſeven other rays, which ſhall paint, on a white body, the ſeven primary colours of nature.

A round hole is made in the window-ſhutter of a dark room, and the ray of light that enters at the hole, falling on a priſm, is refracted, and being thrown on a paper placed at a proper diſtance, forms an oblong ſpectrum that exhibits all the primary colours of nature.

RECREATION XXXIV. p. 142

From two or more of the primary colours to compoſe others that ſhall, in appearance, reſemble thoſe of the priſm.

By mixing any two of the primary colours, as yellow and blue, the intermediate colour, green, will be formed; but theſe mixed colours, though ſimilar in appearance to the primary, yet when viewed

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viewed through a prism, are resolved into the colours of which they are composed.

RECREATION XXXV. p. 144

Out of the three primary colours, red, yellow, and blue, to produce all the other prismatic colours, and all that are intermediate to them.

Three panes of glass are divided, each of them into five equal parts, and over those parts are pasted a different number of papers painted either red, yellow, or blue (Pl. XIII. Fig. 2.) When one of these glasses is put in a box, open at two opposite ends, all the gradations of the colour it contains are visible; and when two of them are placed together, Fig. 3, the intermediate colour appears, with its several degrees.

RECREATION XXXVI. p. 147

By means of the three primary colours, red, yellow, and blue, together with light and shade,

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ſhade, to produce all the gradations of the priſmatic colours.

On ſeven ſquare panes of glaſs papers are paſted that contain all the priſmatic colours, and over them are put a different number of pieces, tinged with a deep ſhade, and they are then placed in a box, in the ſame manner as in the laſt Recreation. Method of printing in colours, p. 148.

RECREATION XXXVII. p. 150

The magical priſm.

A ray of light that comes through a hole made in the window-ſhutter of a dark chamber, falling on a glaſs priſm, (Plate XIII. Fig. 4.) is refracted on a hollow priſm of wood, that revolves on an axis, and in whoſe ſides figures are cut. As this priſm changes its poſition with regard to that of the glaſs, the figures cut out will appear white, yellow, and red, or blue and violet.

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RECREATION XXXVIII. p. 152

The ſolar magic lantern.

A ſmall box that is open at two oppoſite ſides, is placed againſt a hole of the ſame ſize in the window-ſhutter of a dark chamber that faces the ſun. Through this box are paſſed, by a groove, paſteboard blacked, and through which different figures are cut. Theſe figures, when viewed through a priſm, appear to be painted with the moſt lively colours in nature. This Recreation may be diverſified by paſting papers, tinged with different colours, over the figures in the paſteboard.

RECREATION XXXIX. p. 154

The artificial rainbow.

Oppoſite a window on which the ſun ſhines, a glaſs globe filled with water, is ſuſpended by a ſtring that paſſes over a pulley; and when it is drawn up to a certain height, which may be found by trial,

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trial, the colours of the rainbow will appear in it: when it is drawn up a little higher the colours diſappear, and when it is drawn up ſtill higher they appear again, and at laſt totally diſappear. The phenomena of the natural rainbow explained by this experiment, p. 155.

RECREATION XL. p. 158

The priſmatic camera obſcura.

Two holes are made in the ſhutter of a dark chamber (Plate XIII. Fig. 5.) and againſt each of them a priſm is placed, in ſuch manner that both their ſpectrums are caſt upon the ſame ſpot. Several papers, of the ſame dimenſion with the ſpectrums, have lines drawn on them, parallel to the diviſions of the colours, and between thoſe diviſions figures are cut out, which then appear to be painted with all the primary colours. This Recreation may be diverſified by turning one of the priſms round; and by looking at the ſpectrums through another priſm, p. 159.

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RECREATION XLI. p. 160

The diatonic ſcale of colours.

The ſun's ſpectrum is to be largely refracted on a paper, and the diviſions of the ſeveral colours ſet off, when they will be found to correſpond to the diviſions of a muſical chord for the notes of an octave.

RECREATION XLII. p. 162

Colorific muſic.

The ſurface of a hollow cylinder (Plate XIV. Fig. 2.) is divided vertically into ſix equal parts, and horizontally into forty-one parts; in each of the latter parts ſpaces are cut, over which are paſted papers that are painted with the ſeven primary colours. At the bottom of this cylinder is a wheel, an endleſs ſcrew, and a nut; and when it is placed in a caſe, Fig. 3, the endleſs ſcrew is turned

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turned by a handle, which turns the wheel, and raiſes the cylinder by means of the nut at bottom, the height of five of its horizontal diviſions, and conſequently ſhows the ſeveral colours it contains at the eight apertures made in the front of the caſe. A lamp is ſuſpended from the top of the caſe, which hanging within the clinder, ſhows the colours that anſwer to the notes of muſic, and the length of thoſe colours correſponds to the duration of the notes.

PERSPECTIVE RECREATIONS.

RECREATION XLIII. p. 168

To draw on a plane ſurface an irregular figure, which, when ſeen from a proper point of view, will appear ſimilar to a given figure.

A parallelogram is divided into forty-eight equal parts, (Plate XV. Fig. 1.) on which the regular figure is drawn, and its

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its ſeveral parts tranſpoſed, to an equal number of diviſions in a trapezium, where the figure will appear deformed, but when ſeen from a proper point of view, quite regular. The correſponding parts in the parallelogram and trapezium are to be numbered, p. 172— Theſe figures appear to great advantage when painted on the ſide of a gallery, p. 174.

RECREATION XLIV. p. 175

To draw an irregular figure on a plane, which being ſeen from two oppoſite points of view, ſhall repreſent two different regular objects.

The two regular figures are to be firſt drawn on the two parallelograms, (Pl. XVI. Fig. 3.) and then transferred to the diviſions of the parallelogram, Fig. 2. On a board, Fig. 4, of the ſame ſize with the laſt figure, lines are cut, in which

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which a paper, Fig. 5, is paſted, and the diſtorted figure on it: which when ſeen from two proper points of view, will preſent two regular figures.

RECREATION XLV. p. 181

To draw on the baſe of a cone, an irregular figure, which ſhall appear, when ſeen from a proper point of view, not only regular, but elevated above the ſurface of the cone.

The cone is placed in a board, (Pl. XVII. Fig. 1.) with its baſe upward, and at one end of it is fixed a perpendicular plate of glaſs, on which the regular figure is drawn. At the point of view a lamp is placed, by which the figure on the glaſs is thrown on the baſe of the cone, and there traced. The lamp and glaſs are then taken away, and the diſtorted figure, when ſeen from the point of view appears not only regular, but

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erect, and in the ſame ſituation it was on the glaſs.

RECREATION XLVI. p. 186

To draw, eaſily and correctly, a landſcape, or any other object, without being obliged to obſerve the rules of preſpective, and without the aid of the camera obſcura.

In the largeſt end of a box (Plate XVII. Fig. 3.) there is a frame, divided into a number of equal diviſions, and in the oppoſite end is a tube. This box is ſupported on a ſtand. You are provided with a paper that has the ſame number of diviſions as the frame in the box, and looking through the tube you tranſfer the ſeveral objects ſeen through the diviſions of the frame to thoſe on the paper.

RECREATION XLVII. p. 189

Illuminated proſpects.

The top of a print, properly painted, is cut off, and put in a frame, and the lower part in another frame. Theſe two frames

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are placed in a box, (Pl. XVII. Fig. 5.) at different diſtances, and behind them lights are ſet, and when they are viewed from the front of the box, and there is no other light in the room, they afford a very pleaſing appearance.

RECREATION XLVIII. p. 191

Tranſparent illuminations.

Thoſe parts of a print where the light is to appear are cut through with a fine tool. The print is then put in a frame and placed in the box deſcribed in the laſt recreation: behind it is a yellow tranſparent paper, and behind that are lights. Theſe ſcenes are to be moveable, ſo as to repreſent a ſucceſſion of objects differently illuminated.

ACOUSTICS.

DEFINITIONS p. 195
APHORISMS 196

Nature of ſonorous bodies, aph. 1 to 5.—Vibrations of chords, aph. 6 to 9.—Propagation of ſound, aph. 10 to 14.—Strength and reflection of ſound, aph. 15 and 16. RE-

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RECREATION XLIX. p. 201

The eolipiles.

A ſmall metal globe, with a ſlender neck, is thrown, when hot, into a veſſel of water, and when it is put on a fire the water ruſhes out with a great noiſe—this phenomenon improved by fixing the calls uſed by fowlers to the necks of theſe eolipiles.

RECREATION L. p. 202

The communicative buſts.

Two buſts are placed on pedeſtals on the oppoſite ſides of a room, and from the mouth of the one there goes a tube under the floor, to the ear of the other. Therefore, if a perſon ſpeak into the ear of one buſt, another perſon, who applies his ear to the mouth of the other buſt, will hear diſtinctly all the firſt utters; and at the ſame time other people, in the middle of the room, will hear nothing of what paſſes.

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RECREATION LI. p. 203

The oracular head.

This recreation is performed by a ſingle head, and tubes, that go from the ear and mouth of it, to a room underneath, where a confederate hears what is ſaid, and returns an anſwer; and there are wires by which the eyes and lips of the buſt are moved at the ſame time.

RECREATION LII. p. 204

The ſolar ſonata.

A barrel organ is placed in a caſe, that has a glaſs front, behind which is a tube with ſpirits, and on that a cork floats, which, when it riſes to a certain point, by the heat of the ſun, lifts up a catch, and ſets the organ in play; but when the machine is carried into the cold the ſpirits ſink, and the catch again ſtops the organ.

RECREATION LIII. p. 207

An automatous harpſichord.

There are wires that go from the under part of the keys of a harpſichord, and a barrel

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barrel with pins, that take the ends of thoſe wires. Round the axis of the barrel goes a ſtring, that paſſes under the floor, and communicates with a ſmoke-jack, by which the harpſichord is played inceſſantly.

RECREATION LIV. p. 209

A ventoſal ſymphony.

On the top of a houſe there is a vane, (Pl. XVIII. Fig. 3.) at the bottom of which, and within the roof of the houſe, is a wheel, that communicates, by other ſmall wheels and pinions, with a large barrel in the room underneath: to this barrel a number of ſtops are fixed, and cloſe to it are hung twelve bells; therefore, as the vane is turned by the wind, the ſeveral ſmall wheels being put in motion, turn the barrel, and by making it ſtrike the bells, according to the poſition of the ſtops, play the ſymphony.

RECRE-

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RECREATION LV. p. 211
The nocturnal reveilleur.

On the circumference of a wheel are placed a number of bells, and round its axis is wound a rope, at the end of which is faſtened a weight, that reſts upon one end of a moveable lever, and is balanced by a hollow cone filled with ſand, hung to the other end of the lever, but as the ſand runs out the weight deſcends, and by turning the wheel rings the bells.

RECREATION LVI. p. 214
A muſical caſcade.

A large wheel is placed under a caſcade, the water of which is confined to the ends of the wheel; the middle of this wheel conſiſts of bars, in which ſtops are placed, that by ſtriking a certain number of bells play one or more tunes, at pleaſure.

RECREATION LVII. p. 216
Reverberated ſounds.

Conſtruction of a whiſpering gallery—the nature of echoes, p. 217—of reverberated echoes, p. 219.

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RECREATION LVIII. p. 220

The converſive ſtatue.

There are two large concave mirrors, and in the focus of one of them is placed the figure of a man (Pl. XVIII. Fig. 5). The other mirror is placed behind a partition, in which is an opening, concealed by a gauze. When a perſon ſpeaks ſoftly in the ear of the ſtatue, which is exactly in the focus of one of the mirrors, another perſon placing his ear in the focus of the other mirror will hear diſtinctly what is ſaid, and anſwering ſoftly at the ſame point will be heard by the firſt perſon.

RECREATION LIX. p. 223

The great organ.

The body of this noble inſtrument conſiſts of a wind-cheſt, (Pl. XIX. Fig. 1.) over which is placed two boards, that form what is called the ſound-board. In the under ſide of the lower board are ſeveral partitions, and in its upper ſide are

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are cut channels, in which ſliders are placed, in a tranſverſe poſition to the partitions. There are holes made thro' the upper board, ſliders, and under board, into the partitions; and in the holes of the upper board the pipes are placed that produce the ſounds. There are two pair of bellows, by which the air is forced into the cheſt. When any one of the ſliders is drawn out, its holes correſpond with thoſe in the upper board and in the partitions. At the front end of each partition is a valve, under which is a hole into the wind-cheſt; theſe valves are connected with the keys of the organ by wires, ſo that when a key is put down it opens a valve, and the air ruſhes into the partition, and the ſlider being drawn out, it paſſes through the holes in that and the upper board into the pipe placed over it, and makes it ſound.

THE END OF THE SECOND VOLUME.

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